Wissenschaftszentrum Nordrhein-Westfalen
Institut Arbeit und Technik
Kulturwissenschaftliches Institut
Wuppertal Institut für Klima, Umwelt, Energie GmbH

Target 2020:

Policies and Measures to reduce Greenhouse gas emissions in the EU

A report on behalf of
WWF European Policy Office

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Final Report

Authors:
Stefan Lechtenböhmer, Vanessa Grimm, Dirk Mitze, Stefan Thomas, Matthias Wissner

With Support From:
Bernd Brouns, Manfred Fischedick, Thomas Hanke, Wolfgang Irrek, Stephan Ramesohl, Andreas Pastowski, Karl-Otto Schallaböck, Dietmar Schüwer

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HOW TO CUT A THIRD OF EU GREENHOUSE GAS EMISSIONS BY 2020

Freezing Climate Change

Through a concerted strategy of policies and measures the EU can achieve:

- **huge and cost-effective improvements in energy efficiency in all sectors;**
- **reduction of energy consumption to below current levels;**
- **a contribution of renewable energy sources of about 25% of overall energy consumption by 2020...**

...leading to a 33% cut of greenhouse gas emissions in the European Union compared to 1990.

The European Union (EU) has committed itself to limiting global warming to a maximum 2°C average temperature increase above pre-industrial levels. This requires global greenhouse gases (GHG) emissions to be cut by approximately half by the middle of the century. In fact, global emissions will have to peak and decline in the next one to two decades for temperatures to stay below the 2°C threshold.

In March 2005, the Council of the European Union decided that "reduction pathways for the group of developed countries in the order of 15–30% by 2020 […] should be considered". Adoption of such targets by

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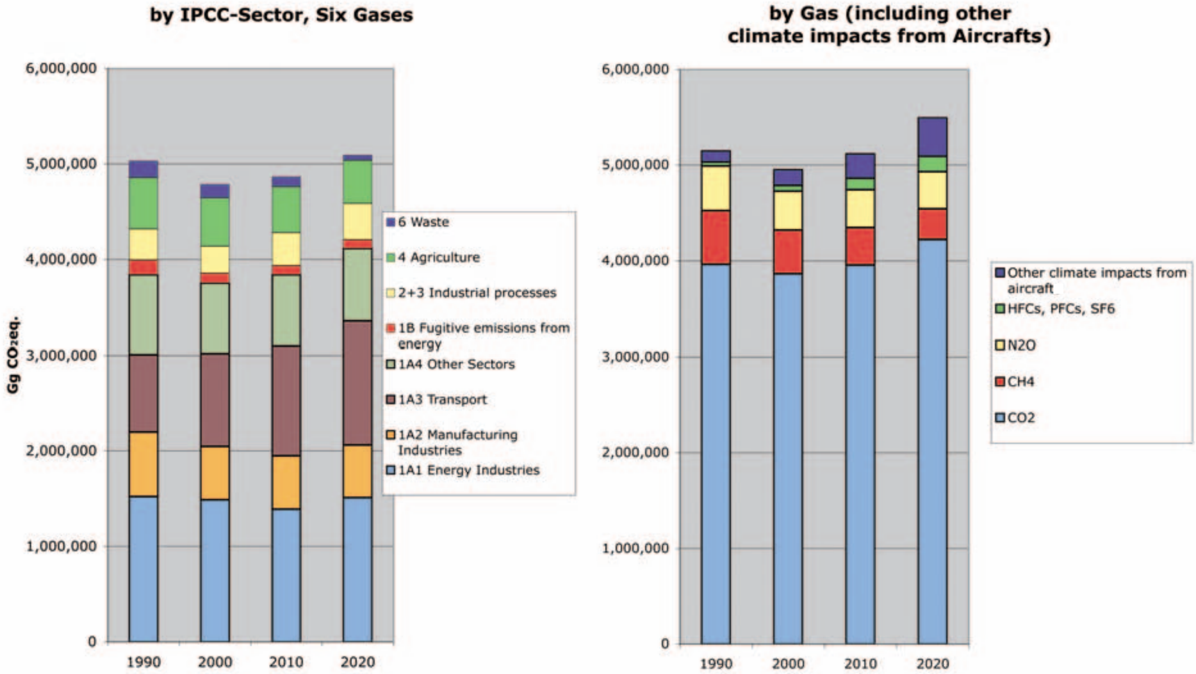
www.panda.org/climate/EUtarget2020

For further information contact:
WWF European Policy Office
Climate Change & Energy Policy Unit
36 Ave. de Tervuren
1040 Brussels
Belgium
Tel: +32 2 743 8800
Fax: +32 2 743 8819
www.panda.org/epo

Figure 1. Greenhouse gas emissions in the BAU scenario, EU25 by sector and by gas



industrialized countries is critical if there is going to be any probability of keeping the global average temperature rise below 2°C.

It is therefore essential that the EU makes a strong and determined commitment to GHG emission reductions and provides leadership in the international process.

Business as usual... or rising to the challenge?

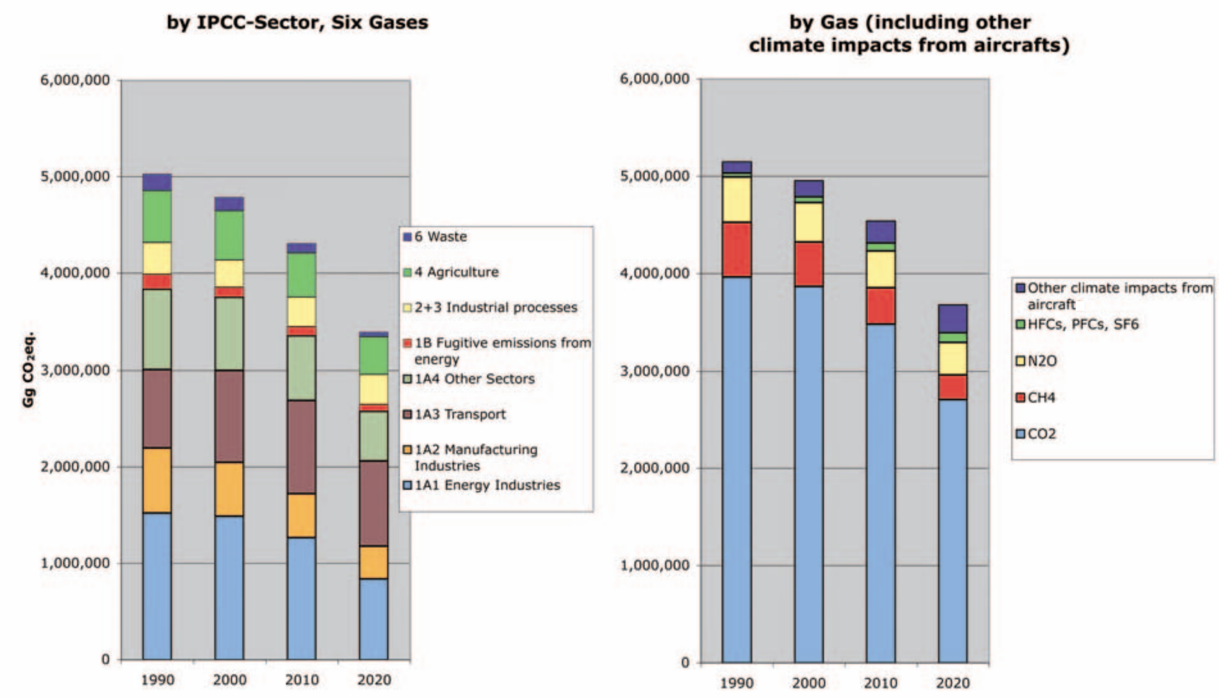
As a contribution to the climate debate within the European Union, a comprehensive analysis of the energy system within the entire EU has been developed for WWF by the Wuppertal Institute. The analysis stresses that a range of policies and measures will be required in order to reduce emissions; these include a strong emissions trading system and mandatory and ambitious energy efficiency and renewables laws. The analysis demonstrates:

- the potential to mitigate greenhouse gas emissions now to achieve a 33% cut in emissions by 2020;
- the policies and measures needed to achieve such reductions; and
- the benefits that would accrue from such measures.

This roadmap for a climate-friendly Europe will bring a range of benefits, including less dependency on foreign sources of energy, cost savings across all sectors, reduction of local pollution due to a switch from coal to cleaner sources, increased job opportunities in the fields of energy efficiency and renewables and, of course, reduced CO_2 emissions. If this roadmap were to be adopted by the European Union, Europe would indeed be a more efficient, secure and environmentally safe place to live and do business.

The key strategies and policies should not be a surprise to anyone involved in climate change or energy work. The first priority must be to drive efficiency and fuel switching through an increasingly stronger Emissions Trading Scheme (ETS). Such an ETS will send the right price signals to the

Figure 2. Greenhouse gas emissions in the Target 2020 scenario, EU25 by sector and by gas



market to adopt energy-efficiency measures and switch from coal to clean power. Another top priority is energy efficiency where many co-benefits enter into the equation. Introducing strong efficiency policies across all levels and all sectors would not only reduce CO_2, but would significantly reduce the demand for foreign sources of energy. It would also create large cost savings. Finally, Europe must continue to invest in renewable energy sources such as biomass, wind and sustainable hydropower. Each of those technologies should be implemented in a sustainable manner, ensuring the avoidance of negative impacts.

The study clearly demonstrates that achieving deep reductions in Europe by 2020 is not a question of available technologies, but rather one of EU leaders taking clear decisions to move in this direction, instead of maintaining a strong dependence on fossil fuels. WWF urges policymakers and business to adopt this roadmap as the path forward for Europe.

The analysis compared two scenarios over the period 1990–2020:

- A business-as-usual (BAU) scenario that assumed continuance of existing policies and measures with no specific emphasis on climate and energy policies. This was based mainly on data and assumptions made in the most recent energy projections for Europe.

- A ‘Target 2020’ scenario which considered the potential to increase energy efficiency and market penetration of renewable energies, a fuel switch to less carbon-intensive fossil fuels such as natural gas, and ways to mitigate rapidly increasing demand, particularly in the transport sector. It assumed a moratorium on new nuclear power plants and compliance with ongoing nuclear phase-out.

With end-use energy efficiency and demand reduction as its two main strategies, the Target 2020 scenario identified the polices and measures necessary to reduce carbon dioxide (CO_2) emissions in the different sectors: electricity, steam and heat generation; renewable energy supply;

residential; the tertiary and services sector; industry; and transport. It also considered measures to reduce other greenhouse gases (e.g. methane) in the waste management and agriculture sectors.

Main findings

Figures 1 and 2 show the results of the respective strategies implemented under the BAU and Target 2020 scenarios.

Energy demand

A continuation of existing policies under BAU will see overall demand for final energy in the different sectors grow between 0.8% and 1.4% per year from 2000 to 2020. Over the same period, an immediate switch to a more ambitious set of measures (Target 2020 scenario) will result in a decrease in final energy demand of 0.4% per year.

Electricity, steam and heat generation

Continuation of current electricity generation from fossil fuels will wipe out the huge emission reductions that occurred in the EU as a consequence of the demise of industry in new members states in the 1990s. Measures such as increased power generation by renewable energy sources, greater use of combined heat and power production (CHP) and a switch to low-carbon fuels like natural gas can reduce CO_2 emissions by as much as 56% (compared with 1990 levels) by 2020.

Renewable energy supply

Under BAU, consumption of renewable energy will reach 9.3% (172 million tons of oil equivalent [Mtoe]) by 2020, with a growth rate of 1.8% between 2000 and 2020. Under Target 2020, it will account for 402 Mtoe, a market share of 24.5% of primary energy supply and an annual growth rate of 6.1% over the same period. With a total supply of 200 Mtoe per year, biomass will account for more than half of renewable energy sources by 2020, of which 61% will be converted into heat and electricity.

Residential

Energy savings of 20% are possible within households under Target 2020, equivalent to a total reduction in energy demand of over 2% of 1990 levels. This can be achieved through using more energy-efficient appliances, better insulation, and more efficient heating and cooling systems. Per capita energy intensity of households also decreases faster under the Target 2020 scenario (attaining a value of 0.566 tons of oil equivalent per head of population in 2020) than under BAU (0.710 toe per capita).

Tertiary sector and services

This sector includes public building, shops, office buildings, warehouses and agricultural premises. Considerably higher energy-saving potentials exist under Target 2020 conditions than under BAU (e.g. in space heating 32% can be saved, water heating 17%, lighting 13%, air conditioning 17%, cooking 23%). By 2020, CO_2 emissions under BAU will show little change from 1990 levels, while in the Target 2020 scenario they will be reduced by 45%. This reduction will be achieved by a range of measures including higher energy efficiency and increasing use of renewable energies.

Industry

Industry accounted for some 28% of energy consumption in the EU in 2000. While this share will remain more or less constant in the future under BAU conditions, overall energy demand by this sector will increase by 19% by 2020, with CO_2 emissions rising to almost 5% above current levels. Stringent implementation of the European Emissions Trading Scheme and other measures, allied to new technologies in motors, pumps, fans, lighting, electronics etc, offer huge savings potential and can stabilize energy consumption at around 5% below 2000 levels by 2020.

Transport

This is the fastest-growing sector in the EU in terms of energy demand and CO_2

emissions. If existing policies and measures are implemented successfully, by 2020 emissions will still be above 1990 levels by some 466 million tons of CO_2. Under the Target 2020 scenario, emissions will amount to some 854 megatons in 2020, 397 megatons (or 31.7%) of CO_2 less than under business as usual. This equates to a stabilization of emissions at roughly 1995 levels.

Waste

Full implementation of the EU Landfill Directive by member states, as assumed in the BAU scenario, will reduce GHG emissions from waste management by more than two-thirds. However, increased recycling quotas and improving technologies such as mechanical or biological waste water treatment under the Target 2020 scenario make a further annual emission reduction of about 10 million tons of CO_2 equivalent possible by 2020.

Agriculture

The BAU scenario already shows a clear downward trend in GHG emissions, such that by 2020 a reduction of more than 15% is likely in comparison to 1990 levels. However, the Target 2020 scenario demonstrates that emissions can be reduced by a further 67 million tons of CO_2 equivalents, representing an overall reduction of 28% from 1990 levels. This can be achieved through, for example, better storage conditions for manure, improved fertilizer use efficiency, and a better match of nitrogen supply with crop demand leading to reductions in nitrous oxide.

Conclusions

An integrated and active climate protection strategy for the EU, while ambitious, is clearly feasible. To achieve this, the EU must speed up improvements in energy efficiency and adapt power generation systems to renewable energy supplies.

Through a concerted strategy of policies and measures the EU can achieve:

- huge and cost-effective improvements in energy efficiency in all sectors;
- reduction of energy consumption to below current levels;
- a contribution by renewable energy sources of about 25% of overall energy production by 2020.

Importantly, a 33% reduction of GHG emissions from fuel combustion is possible for all EU25 member states by 2020, even with a moratorium on nuclear energy. Non-energy GHG emissions can also be reduced by 33%, chiefly in the agricultural sector (e.g. by increased use of biogas) and the waste sector (e.g. by strict compliance with the Landfill Directive).

An active climate protection strategy can yield further benefits in the form of massively reduced risks of energy shortages and energy price peaks, as well as improved resilience of the European energy system. Such a strategy releases the European economy from high energy costs, creates a net increase in employment – the European Commission Green Paper on Energy Efficiency (March 2005) estimates that an energy saving of 20% by 2020 could generate up to one million jobs in the EU – and also reduces other environmental burdens.

Recommendations

WWF urges European Union policy-makers to:

1. Abandon the disastrous "business-as-usual" approach and develop a comprehensive and ambitious energy strategy that will increase energy security, make the European economy energy efficient, and reduce EU emissions of CO_2 by a third by 2020;

2. Develop and adopt a comprehensive climate policy strategy, both at the EU level and at member state level;

3. Further develop and strengthen the European Emissions Trading Scheme (ETS). The ETS should form a central part of the overall strategy as it covers sectors responsible for 60% of the total emission reductions expected by 2020. For the ETS to achieve its full potential, strict and reliable long-term emission reduction paths are crucial, with EU member states responsible for achieving national caps on emissions;

4. Develop and adopt a comprehensive set of sector- and technology-specific policies and measures for:

   – energy end-use and supply efficiency
   – combined heat and power (CHP) production
   – electricity generation from renewable energies, and
   – thermal uses of renewable energies.

   Particular attention should be given to energy efficiency in transport (e.g. increasing fuel efficiency in all modes of transport, increased market share for biofuels) and in households (e.g. rebate schemes for thermal insulation, obligatory solar heating for new and renovated homes);

5. Carry out ecological finance reform, particularly removal of direct and indirect subsidies for unsustainable energy generation and use pattern;

6. Fast-track EU directives on energy services and energy-efficiency programmes; this will create multi-billion Euro markets for services and technologies;

7. Give legal and fiscal support to renewable energies and combined heat and power production;

8. Establish regional and national energy agencies and consumer organizations which can intensify the drive for energy efficiency, CHP and renewable energies.

A call to action…

WWF calls on the EU to adopt a target of cutting greenhouse gas emissions by one third by 2020. The EU can now decide to grasp the technical, political and economic opportunities to do so. This will help to ensure that the increase of the world's average temperature remains less than 2˚C above pre-industrial levels. It will also help the EU to renew and intensify its leadership in international climate change negotiations.

WWF

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For further information contact:

WWF European Policy Office
Climate Change & Energy Policy Unit
36 Ave. de Tervuren
1040 Brussels
Belgium
Tel: +32 2 743 8800
Fax: +32 2 743 8819
www.panda.org/epo

2 Introduction

With the entry into force of the Kyoto Protocol on 16 February 2005, a formal process on the post-2012 regime has started. Some countries are already beginning to consider what level and types of targets should be the basis for such discussions. For example, in March 2005 the Council of the European Union decided that "reduction pathways for the group of developed countries in the order of 15-30% by 2020 […] should be considered" (EU 2005). Such targets will be necessary by industrialized countries if there is going to be any probability of keeping the global average temperature rise below 2°C in relation to pre-industrial levels. The literature includes numerous studies about the devastating impacts that could occur if temperatures were to rise above this threshold.

It is therefore essential that the EU makes its commitment to such reductions early on in the process, thus providing the necessary leadership in the international process. In order to contribute to that EU analysis and consideration, a comprehensive scenario of the energy system of the EU25, including energy-related and non-energy-related emissions by 2020 has been developed by the Wuppertal Institute for WWF. The analysis demonstrates:

- the potential to mitigate greenhouse gas (GHG) emissions now and through to 2020;
- the policies and measures needed to achieve such reductions;
- the benefits that would accrue from such GHG mitigation measures.

The study demonstrates that a reduction of greenhouse gases of more than 30% by 2020 for the EU25 is feasible, reasonable and – to a large extent – cost effective. The analysis stresses the major role that energy efficiency plays in all sectors and in all member states. This analysis includes a comprehensive policy package showing how to achieve such a 30% target by 2020, and the expenses and benefits of such a policy set compared to a business-as-usual scenario. These results refer to EU-domestic action[1] only, including the EU Emissions Trading System, which is identified as a key policy to achieve such reductions. It excludes land use, land-use change and forestry, and the purchase of credits from outside the EU25 through the Clean Development Mechanism (CDM) or other emissions trading systems. The inclusion of such activities could therefore boost Europe's GHG emissions reductions above and beyond the 30% figure.

2.1 Background to the study

The Kyoto Protocol requests the first Conference of the Parties – serving as a meeting of the Parties to the Protocol (COP/MOP1) – to begin the process of reviewing the commitments of industrialized country Parties (Article 3.9), and the second Conference (COP/MOP2) to fully review both the Protocol and the United Nations Framework Convention on Climate Change (UNFCCC). While the Tenth Conference of the Parties (COP10) agreed to convene a "seminar" on the subject, no significant steps to elaborate post-2012 targets and regime have been discussed formally. This task is now on the international agenda (Brouns et al. 2004).

The EU has committed itself to limiting global warming to a maximum 2°C average temperature increase above pre-industrial temperatures (EC 2005). This threshold requires,

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1 Activities within the EU25.

according to the most recent research, that global GHG emissions will need to be cut by approximately half by 2050 (Hare & Meinshausen 2004). In fact, global emissions will have to peak and decline in the next one to two decades for temperatures to stay below the 2°C threshold. This consequently indicates that industrialized countries will have to reduce their GHG emissions by approximately 60-80% by 2050 in order to leave legitimate potential for economic growth and associated higher emissions in developing countries (European Commission 2004a) . In addition, some developing countries will also need to make commitments to develop in a less carbon intensive manner in a step-by-step manner. To achieve this challenging goal, rapid action is needed. Future commitment periods under the Kyoto Protocol with a likely time horizon of 2013 to 2017 and 2018 to 2022 will thus need to see substantial reduction targets by developed countries. This will be a precursor for further action and commitments by developing countries. The debate on these targets has already started. The French government, for example, included in its “Plan Climat 2004” a 75-80% reduction target to be achieved by 2050 (France 2004) and the UK aims at a 60% reduction of its CO_2 emissions by mid-century (UK 2003). In addition, the Czech Republic, Germany, The Netherlands and Sweden have adopted ambitious mid- and long-term reduction targets (see Brouns & Ott 2005). In January 2005, the European Parliament published a resolution on the outcome of the Buenos Aires Conference on climate change. It emphasized “the necessity of significantly enhanced reduction efforts by all developed countries in the medium term to be able to meet the long-term emission reduction challenge” which it quantified for industrial countries “of the order of 30% by 2020” and “of 60-80% by 2050”. It also called on the EU “to adopt reduction targets at the 2005 Spring European Council which are in line” with these objectives (European Parliament 2005). The European Commission in its communication ”Winning the Battle Against Global Climate Change” supported the necessity to limit temperature increases to a maximum of 2°C worldwide compared with pre-industrial levels and confirmed its will to take international leadership towards combating climate change (EC 2005a). It also documented the relatively low economic costs to do so without even calculating the consequent benefits of emissions reductions.

With this background, WWF commissioned the Wuppertal Institute to conduct an integrated[2] scenario analysis of GHG-emission reduction potentials of the EU25 for the year 2020.

2.2 Aims of the study

The integrated scenario analysis carried out here aims to elaborate, describe and evaluate strategies and paths for the European Union to achieve significant reductions of its domestic greenhouse gas emissions by 2020.

For this purpose we developed a strategy scenario called the “policies and measures (P&M) scenario”. This scenario relies on a baseline derived from the energy and transport projections for Europe (Mantzos *et al.* 2003). Its strategies and assumptions are based on evaluation and extrapolation of detailed analyses in all sectors, for many countries, for important energy-using goods and appliances. Here a number of most relevant studies were chosen (see ch. 4 and Annex II).

[2] Integrated means in this case that all greenhouse gases regulated in the KP and the respective potentials and policy initiatives are integrated into the analysis.

In the scenario analysis no explicit ranking and selection of GHG mitigation potentials and strategies by cost criteria has been made, due to the problematic nature with regard to the different cost and benefit functions of actors in different countries and sectors and under different perspectives (e.g. micro-economic: company level; macro-economic: state level). Instead, potentials were selected with regard to their cost-efficiency (first on micro / company, then on macro / national level) and strategies were based in general on an implementation of about 80% of the available macro-economic potentials; e.g. the potentials which are cost efficient at a national level – calculated with long-term real interest rates typically between 3 and 5% and payback times equal to economic lifetimes of investments[3]. Policies and strategies have been selected using expert knowledge rather than mathematical optimization algorithms.

Overall, the analysis is aimed at evaluating the available potential for GHG emissions reductions by sector as well as the strategies that need to be implemented to achieve this potential. It will thus show how ambitious GHG-mitigation targets can be reached.

2.3 Integrated Scenario Analysis

In order to analyse whether and how a reduction of GHG emissions in the order of magnitude of about 30% below 1990 levels by 2020 can be reached, we conducted an integrated scenario analysis of the EU25. The results presented here focus on energy-related GHG emissions.

Our analysis consists of two scenarios. The Business-as-usual (BAU) scenario assumes continuing policies and measures with no specific emphasis on climate and energy policies, neither with regard to additional policies that might be implemented since 2003 to meet the Kyoto Protocol targets, nor to rising energy prices and increasing concern about limitation of resources. The BAU scenario is mainly based on the data and assumptions made in the most recent energy projections for Europe (Mantzos *et al.* 2003). The main purpose of this scenario is to serve as reference to the Policies and Measures (P&M) scenario.

In the P&M scenario existing cost-effective potentials to increase energy efficiency and ambitious targets for market penetration of renewable energies are exploited by targeted policies and measures. In addition, a fuel switch to less carbon-intensive fossil fuels such as natural gas, and policies and measures to mitigate the exploding demand in the transport sector, are assumed to be effective in the P&M scenario. The P&M scenario includes a moratorium on new nuclear power plants and compliance with the nuclear phase-out in respective countries. An overview of the BAU and P&M scenarios is provided in Chapter 3, followed by a sectoral description in Chapter 4.

The quantification and combination of potentials, strategies, policies and measures, and the calculation of scenarios were carried out using the Wuppertal Scenario modelling system.

- This system uses a technology-oriented, sectoral, bottom-up approach. Corresponding to its relevance for GHG-emissions, the energy sector is modelled with the greatest detail using appliance or end-use specific sub-models for every demand sector (households, tertiary, industry, transport) and a purpose-oriented

[3] Economic lifetime varies from typically 12 to 15 years for appliances in residential and tertiary sectors, to 25 to 30 years for retrofitting of buildings, industrial equipment and power plants (cf. Blok 2005).

model of the transformation sector[4]. GHG emissions in the energy sector are calculated based on the final and the primary energy balance. CH_4 and N_2O emissions in the energy sector are calculated by sub-sector using a simplified approach based on current sector-specific implied emission factors[5].

- Other sectors and greenhouse gases are covered by specific sub-models which are adapted to the currently (limited) information available in these sectors.
- The system applies a heuristic (i.e. expert-based) approach in order to formulate potentials and strategies and in order to estimate market penetration rates of new technologies, market shares of fuels etc[6].
- The geographical breakdown of the scenario analysis carried out here is by the EU15 member states and new member states (NMS). For these two groups, specific assumptions on potentials, strategies, policies and measures have been made respectively. Country-specific considerations have been incorporated by expert estimates where necessary.
- The basic data, economic assumptions and the main results for the BAU scenario have been derived from the latest available EU energy and transport projections (Mantzos *et al.* 2003). For other greenhouse gases (CH_4 and N_2O from fuel combustion) and other sectors (fugitive emissions from energy, emissions from industrial processes, agriculture and waste management) our own BAU scenarios have been developed. Also, for the transport sector the BAU has been revised (see below).
- The core of this scenario study combines the latest available sectoral studies, scenarios and plans for all emission sectors and policy fields. From a compilation – and where necessary – extrapolation of these studies in every sector, the available potentials and feasible strategies have been derived and combined to form a comprehensive policy scenario. By creating this scenario, comparable philosophies have been applied in every sector as far as possible in order to produce a homogenous and consistent scenario.
- The main underlying assumptions for the selection, calculation and extrapolation of the sectoral scenarios are:
  - the delivery of substantial emissions reductions versus the BAU scenario by an exploitation of roughly 80% of the available emissions reduction potential;
  - the emissions reduction potentials taken into account for the P&M scenario in all sectors are available, proven by at least one study for as many countries as possible, typically cost effective in a national economic perspective (see above); and

4 A description of model detail and philosophy as applied for Germany is given in Fischedick, Hanke and Lechtenböhmer (2002). For this work the models have been adapted using the same philosophy but partly lower disaggregation levels.

5 To achieve a more precise calculation of CH_4 and N_2O from the combustion of fuels, a technology-specific approach would be needed (see IPCC 1996, 2000). However, the contribution of these gases to the total GHG emissions of fuel combustion is well below 2.5%, which justifies a simpler approach.

6 The expert-based approach is described in detail in Lechtenböhmer & Thomas (2004). However, for the scenario analysis described here a simplified approach was used due to budget and time constraints.

- o attainable by appropriate and realistic strategies. These strategies shall be preferably decided, or the extrapolation of existing strategies for future periods or additional countries or strategies proposed, by relevant actors or studies. Further details on selected potentials and strategies and underlying studies and assumptions are given in the sectoral description (see Chapter 4 and Annex II).

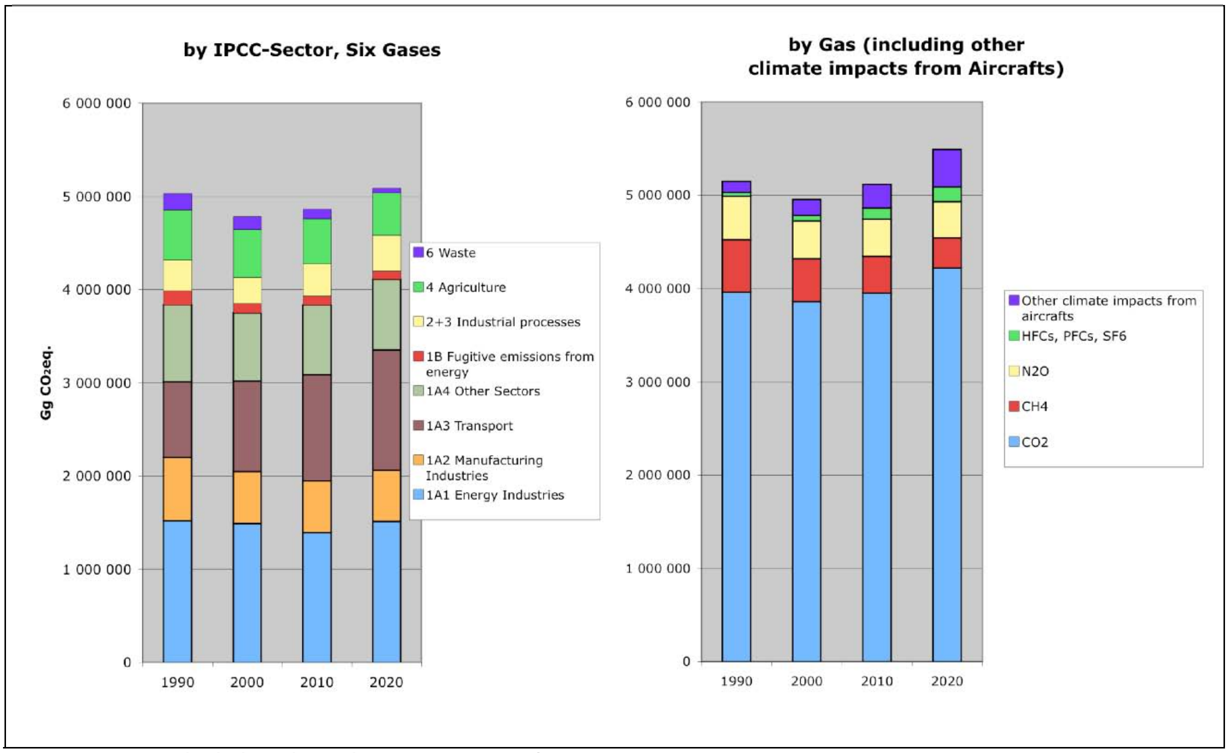
- o Through implementing selected and – if necessary – modified/extrapolated sectoral strategies in an integrated scenario calculation framework, overlaps (with regard to double counting of emission reductions resulting from energy savings in the demand and supply sectors) have been removed and synergies accounted for.

3 Overview of scenario results

3.1 The Business-as-usual scenario

To a large extent the results of the Primes and ACE energy models published in "European energy and transport trends to 2030" by DG TREN (Mantzos *et al.* 2003) are taken as the Business-as-usual (BAU) scenario. In particular, the economic assumptions of a less than 1% population growth between 2005 and 2020 and a parallel increase in GDP of about 43%, as well as the demand baseline from the European energy and transport trends, are used as input data. Key results on the greenhouse gas emissions of the BAU scenario are shown in the following figure.

Figure 1: Greenhouse Gas Emisisons in the BAU scenario, EU25 by Sector and by Gas



Source: own calculations based on Mantzos *et al.* 2003

Although the BAU scenario includes considerable energy-efficiency improvements in all energy-consuming sectors, increasing renewable energy shares and a decoupling of gross energy consumption growth (+0.7% pa) from GDP growth (+2.4% pa), no reduction of GHG emissions from energy use can be achieved by 2020 under BAU conditions. On the contrary, CO_2 emissions from fuel combustion are expected to increase by 10% of 2000 levels.

Where total GHG emissions are concerned in other relevant sectors, emission reductions already occurred since 1990 or can be expected in the BAU-scenario. Emissions in the waste sector will decrease by almost 70%, mainly due to regulations under the landfill directive. Fugitive emissions from energy have significantly decreased, due mainly to the closing of coal mines and improved capture of methane from mines. This trend will be sustained at a reduced rate. In the agricultural sector, a reduction in the number of cattle is the key reason for the decreasing emissions. However, non-energy related GHG emissions in the industrial sector (including use of solvents) are expected to rise again. This is mainly due to the increased use of fluorinated gases, which is not compensated for by the reduction of other emissions from industrial processes.

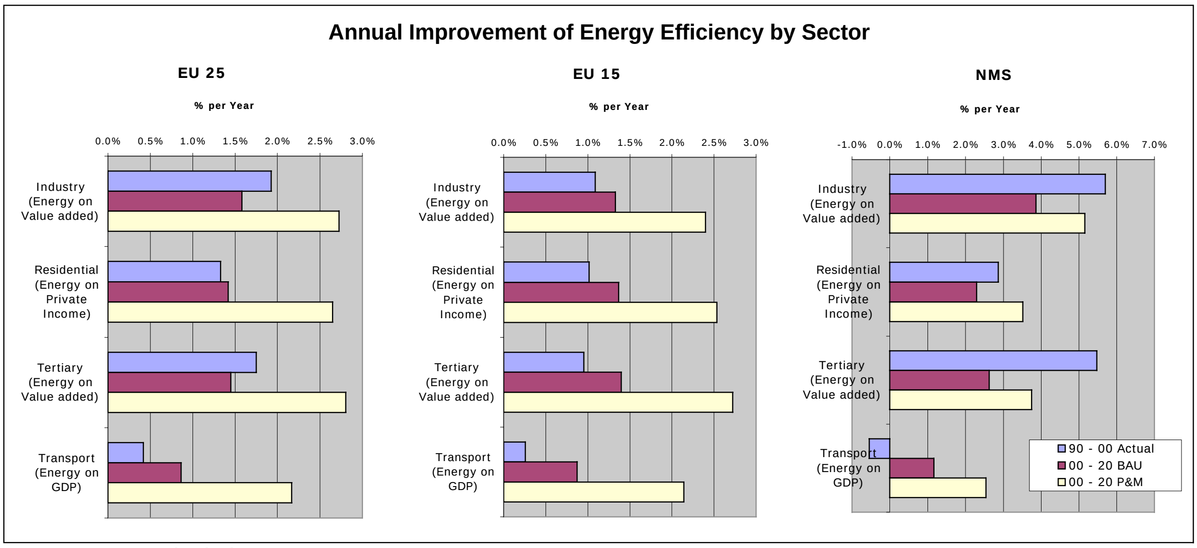
Based on our model calculations, these results indicate that GHG emissions of the EU25 are going to rise again and by 2020 reach a level of about 1% above 1990 levels. In 2010 the reduction is approximately 3.3%, just half of the reduction committed to by the EU under the Kyoto Protocol (-8% reduction of all six gases in the EU15 and an average reduction of 7.8% for the NMS).

3.2 The Policies and Measures scenario

In the Policies and Measures (P&M) scenario an active and ambitious strategy to reduce European Union GHG emissions is assumed. This strategy contains the following key elements:

- As GHG emissions from fuel combustion, mainly CO_2, account for more than 75% of all GHG emissions of the EU, this sector is also key to mitigation strategies, contributing about 77% to all emission reductions set against 1990 levels, and as much as 90% when set against the BAU scenario by 2020.
    - o Energy efficiency in all demand sectors is one of the core strategies. Through a comprehensive bundle of cross-cutting and sectoral policies, improvement in energy efficiency can be doubled, as compared to the BAU scenario and the past decade (see Figure 2). Under this strategy final energy demand in the EU25 can be reduced by 0.4% per year, which means a reduction of more than 20% compared with BAU. Thus, energy-efficiency gains alone are responsible for more than 50% of GHG emission reductions in the P&M scenario.

Figure 2: Annual Improvement of Energy Efficiency by Sector



Source: own calculations

- o Accelerated expansion of the use of renewable energies to about 80% of the available mid-term potential is the second main GHG mitigation strategy. With an increase of 7.4% per year, the use of renewable energy sources reaches 25% of gross domestic energy consumption by 2020. The bulk of it lies in the energy transformation sector, where about 38% of all electricity and steam generation will be based on renewable energies by 2020. This can be achieved by ambitious targets and a mix of best practice policies such as fixed feed in tariffs.

- o Doubling of combined heat and power (CHP) production by replacing old coal-fired plants with gas-fired units and/or biomass-fired units, and active promotion of decentralized CHP generation in micro-CHP is the third important component.
- o To this should be added a fossil fuel switch towards lower carbon-emitting fuels and an active efficiency strategy on the supply side.
- o This means that the necessary high re-investment needs in power plants that will occur in the EU over the next decade will be based mainly on CHP plants and gas-fired units with best available technology. However, when viewed against the BAU scenario the necessary re-investments in fossil power plants can be cut by half.

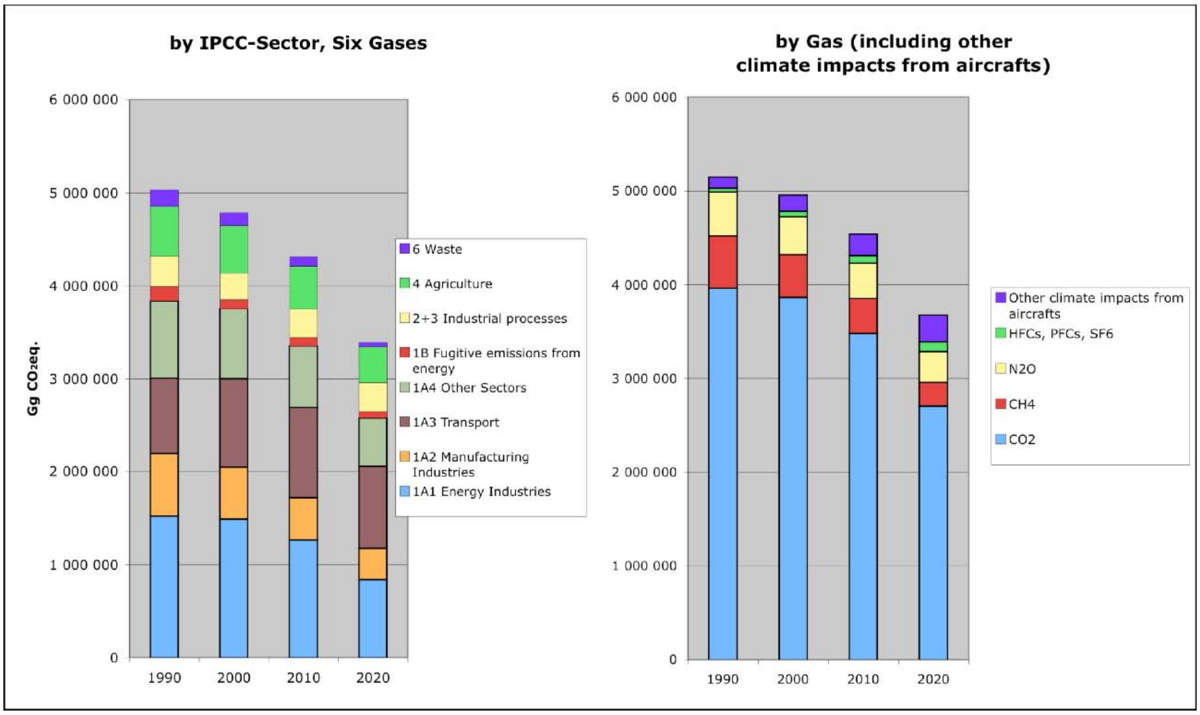
- In most of the other non-energy GHG emitting sectors, high emissions reductions are expected even in the BAU scenario (see above). This is the reason why these gases contribute an equal share of some 23% to GHG emission reductions set against 1990 levels, but contribute only 10% to emission reductions vs. BAU as a higher share of their reduction potentials will be used even under BAU conditions. The additional emission reductions in the P&M scenario can be achieved through, for example, the use of biogases and other measures in the agriculture sector, by further policies and measures to achieve higher recycling rates for waste, by utilizing coal mine methane, by the switch to lower-emitting cement types (with lower clinker content), and by the switch to lower-emitting processes or the installation of emission-preventing technologies[7].

Figure 3 shows the result of the strategies implemented in the P&M scenario. The GHG emissions from fuel combustion can be reduced by 33% compared to 1990 levels. When viewed against the BAU scenario this means a reduction of 37%. This trend is mirrored in the emissions of the main greenhouse gas, CO_2, which are reduced by 32% compared to 1990.

Fugitive GHG emissions from energy production and distribution, emissions from the waste sector and emissions from agriculture can also be significantly reduced. Here a high level of reductions has already been achieved or can be expected by 2010. The emissions of methane (CH_4) and N_2O will have fallen by 55% and 29% respectively by 2020. Only the emissions of the fluorinated gases will increase significantly. This is the main reason why the non-energy emissions of industrial processes will be reduced by just 5% by 2020.

[7] For these sectors and gases the data and information basis on emitting processes are still incomplete with regard to the EU25. Therefore the emission reductions were only conservatively estimated. A more detailed analysis will probably identify more cost-efficient GHG reduction potentials.

Figure 3: Greenhouse Gas Emisisons in the P&M Scenario, EU25 by Sector and by Gas



Source: own calculations

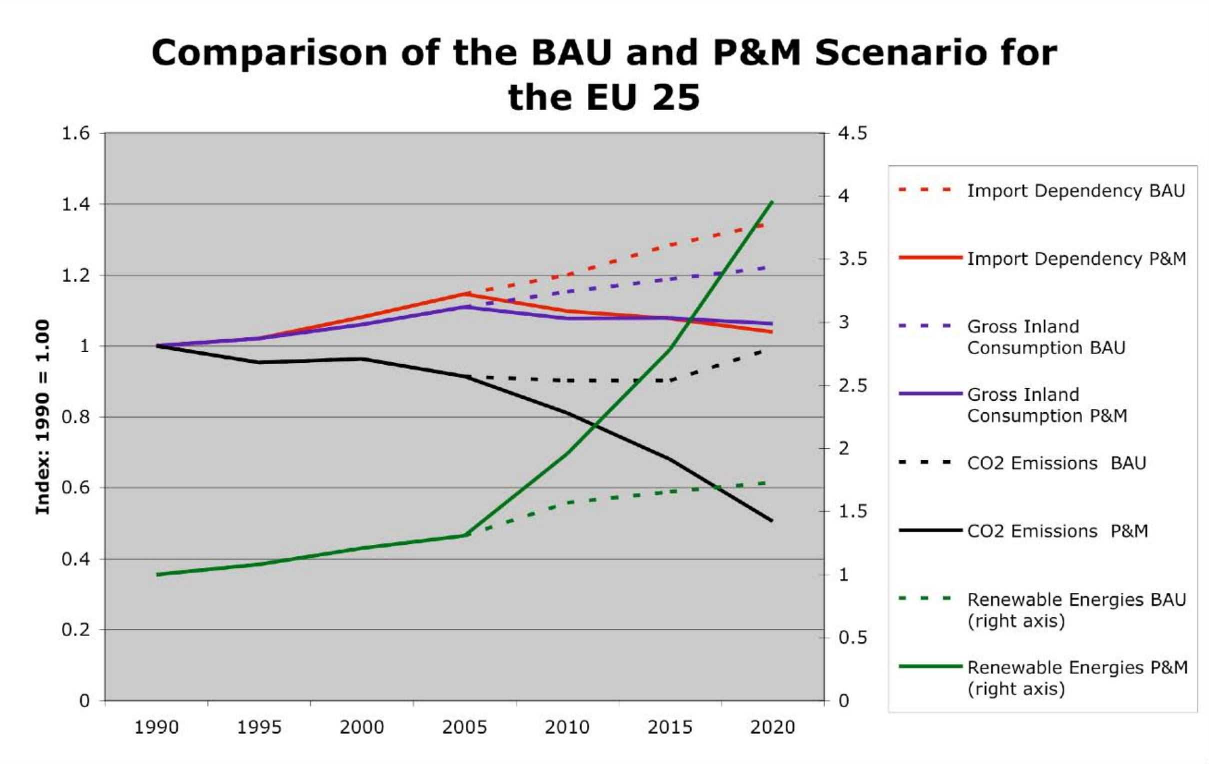
Overall, GHG emissions in the EU25 can be reduced by 33% of 1990 levels. This means that the energy sector and the other sectors have more or less equal shares in emission reductions[8]. However, if the impact of stratospheric aircraft traffic (which is currently not subject to international regulations) is included in this balance[9], the overall emissions reduction will only be at about 29% of 1990 levels.

Compared with the BAU scenario, the important features of the P&M scenario are that – by implementing an active strategy – the currently prevailing unsustainable trends can be broken (see Figure 4). The increasing trend in gross domestic energy consumption will be turned into a decrease. Supported by a rapid speeding up of uptake rates of renewable energies, this will turn the slow but steady increase in CO_2 emissions into a strong decrease, as well as slowing down import dependency.

8 As compared to 1990. Compared to the BAU scenario the share of fuel combustion is 90% of all emission reductions due to high emission reductions having been achieved already in the other sectors or expected to occur even under BAU conditions.

9 The precise dimensions of this impact are still subject to basic research. Current research reveals, however, that the impact of stratospheric air traffic is about three times the emissions of CO_2 only (Schumann 2003, Wit *et al.* 2005). These effects will be quantified very approximately, as a separate category, by assuming that all other impacts are twice the size of CO_2 emissions.

Figure 4: Comparison of Key Indicators of the BAU and P&M Scenario for the EU25



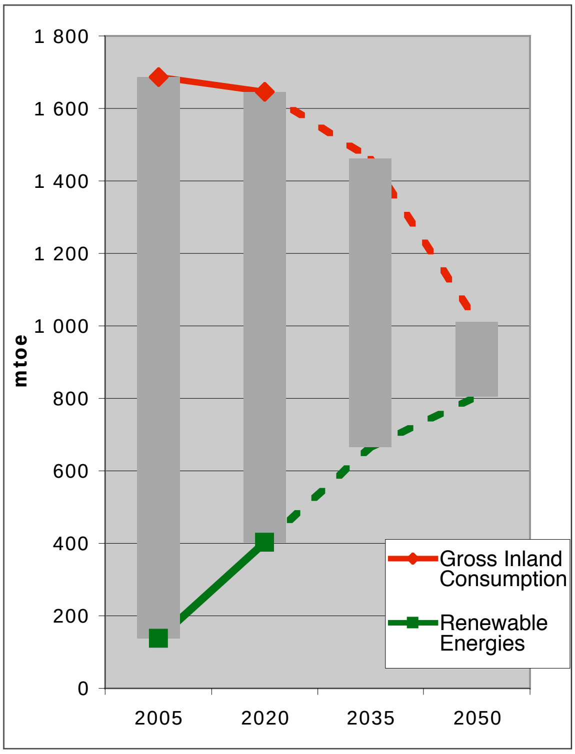
Source: own calculations

3.3 Outlook: Prolonging the high energy-efficiency path as a key for the long-term emissions reduction strategy

The Policies and Measures scenario described in this study aims at a 30% reduction of European Union member state GHG emissions by 2020. This will put the EU on track to achieve a long-term sustainable emissions level and will also be an important first step towards the stabilization of atmospheric concentrations of greenhouse gases at a level “that would prevent dangerous anthropogenic interference with the climate system”. The main elements of the scenario are a more than doubling of the energy-efficiency improvement set against past and current levels, and an active and broad market introduction of renewable energies.

In the long term, preventing dangerous climate change would most probably require atmospheric GHG concentrations to stabilize well below 550 ppmv CO_2 equivalent (EU 2005; Hare & Meinshausen 2004; WBGU 2003). This would require global emissions to peak at around 2015-2020 and a reduction of global energy-related CO_2 emissions by about 45-60% from 1990 levels by 2050, accompanied by substantial reductions of other greenhouse gases (WBGU 2003). As a consequence for EU and other industrial countries this means that they should aim at an emissions reduction of about 80% by 2050. To achieve this will require a prolongation of the development introduced by the P&M scenario.

Figure 5: Gross Inland Energy Consumption and Renewable Energy Sources – Long Term Strategy for the EU 25 Until 2050



Source: own calculation based on Blok (2005) and Fischedick *et al.* (2002)

- Energy efficiency has to be developed further by means of technology and innovation, as well as by a supportive market ready to adapt optimal technology. Blok (2005) shows by a broad range of examples from all energy demand sectors that an annual energy-efficiency improvement of 5% and more is possible using new technologies, and has even occurred in a number of energy appliances over longer periods. If such an innovation ratio were maintained over a period of 50 years, it would mean that energy-efficiency improvement can be accelerated to an average of 3% per year set against the BAU scenario, thereby achieving a constant decrease of energy consumption by 1% per year. This would be a consequent prolongation of the efficiency path described in the P&M scenario for 2020. By adopting such an ambitious long-term “innovation for energy efficiency” strategy, final energy consumption could well be cut by 40% against current levels by the middle of the century.
- The use of renewable energies will triple by 2020 in the P&M scenario and reach a share of 25% of gross domestic energy consumption. A further extension of this trend should achieve a doubling of renewable energy use, by which renewable energies could supply up to 80% of all gross energy consumption by 2050.

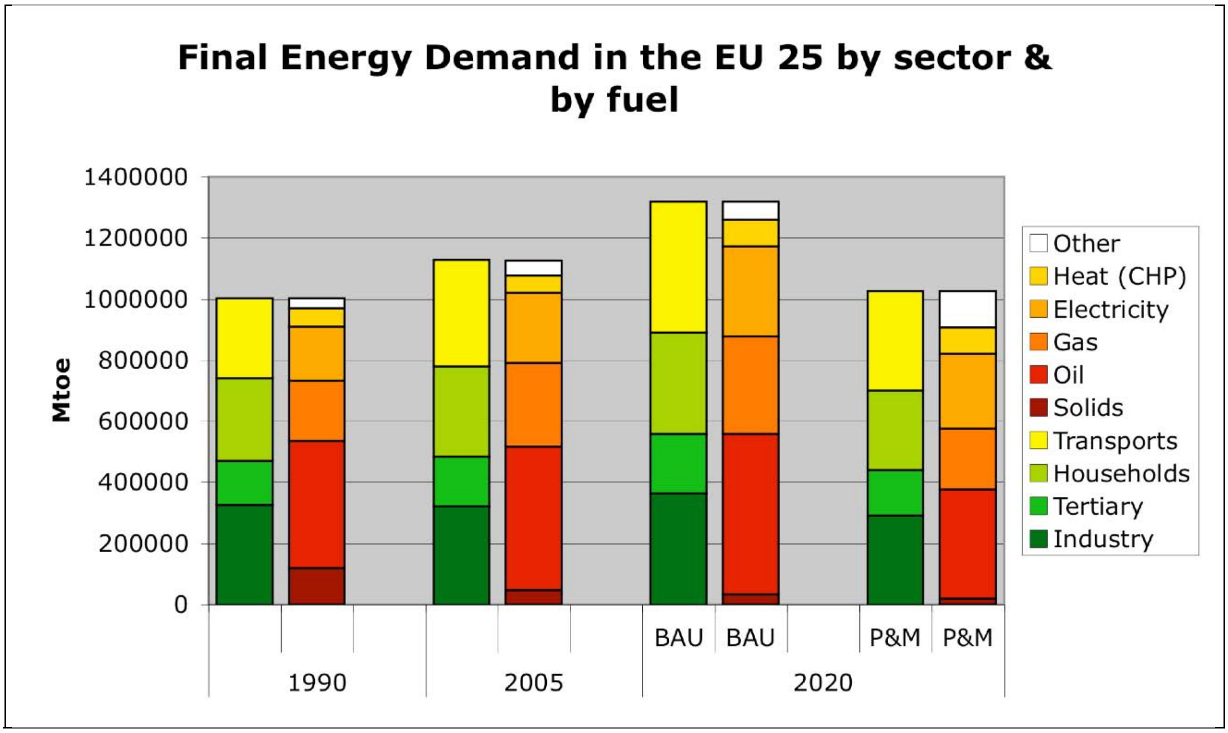
By combining a strategy of continuous innovation in energy efficiency and a further expansion of renewable energy sources, the EU25 could find itself capable of achieving a GHG emissions reduction of 80% by 2050[10]. However, such a reduction requires a significant structural change in energy systems and ambitious and effective policies in emissions trading, energy efficiency and renewables.

[10] Such a strategy was further developed for Germany by Fischedick et al. (2002), who showed that the strategy is able to achieve an 80% decrease in GHG emissions by 2050.

4 The P&M scenario by sector

To explore how the alarming course of the BAU scenario can be shifted towards a more sustainable direction, an emissions reduction scenario was developed for the EU25. The P&M scenario includes additional or improved policies and measures, such as strengthening the ETS, to enhance emissions reductions. Supplementary to the energy-efficiency strategy, a renewable energy strategy – based on the EC renewable energy mid-term potentials (European Commission 2004b) – can be shown to produce substantial additional emissions reductions. As an effect of the two strategies combined, the share of renewable energies will increase to 25% of total primary energy supply and about 38% of electricity production in the EU25 by 2020 (BAU: 7.15% / 7.32%). An additional benefit of the P&M approach would be holding import dependency of the EU25 at almost current levels of around 55%, while in the BAU scenario dependency increases to almost 70% (see Figure 6).

Figure 6: Final Energy demand in the EU 25 by sector and by fuel, comparison of scenarios



Source: own calculations; for BAU, Mantzos *et al.* 2003

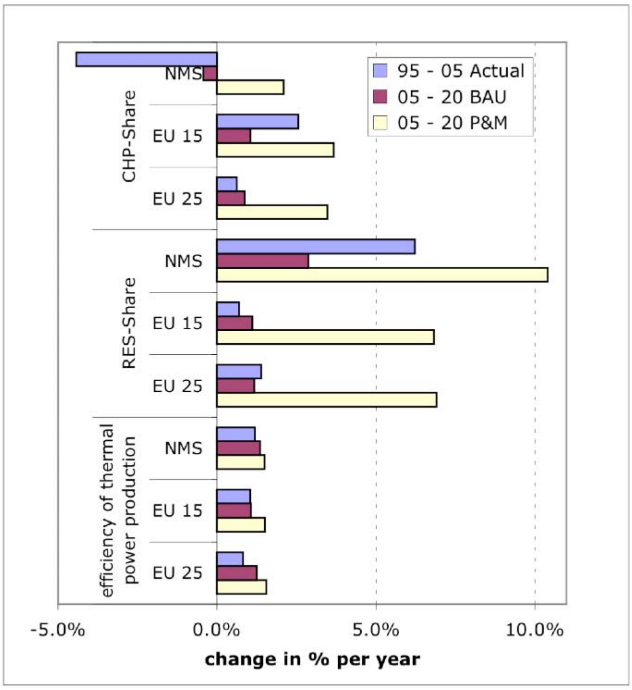
The development of the final energy demand in the BAU scenario shows a demand growth in the different sectors of between 0.8% and 1.4% per year from 2000 to 2020 (see Figure 6). By comparison, the final energy demand in all sectors in the P&M scenario decreases by more than minus 1% per year compared to BAU.

End use energy-efficiency and demand reduction are the most important strategies in the P&M scenario with regard to reversing the trend in energy consumption growth. The policies and measures required for each sector to realize this change in final demand development are discussed in the following sections and include such policies as strengthening the European Emissions Trading Scheme, mandatory and ambitious energy-efficiency policies and strong targets on renewable energy.

4.1 Electricity, Steam and Heat Generation

In 2000, about one-third of the total CO_2 emissions in the EU25 arose from electricity and steam generation (Mantzos *et al.* 2003). This sector therefore plays a crucial part in any climate policy strategy. We demonstrate here that through active promotion of electricity savings (see also demand sectors), accelerated expansion of CHP and increased use of renewable energies, CO_2 emissions in this sector can be cut by almost half compared to 1990 levels. This will require an ambitious set of policies such as those mentioned above.

Figure 7: Improvement of energy efficiency, RES-share and CHP-share in power generation



Source: own calculation

The cornerstone of the strategy is to foster electricity savings in all demand sectors. Together, a reduction of about 1.4% per year can be achieved compared with BAU (see Figure 7). On this basis, four key policies are assumed for the supply side:

- o Increased power (and combined heat) generation by renewable energy sources (RES):

  The share of renewable energies increases by 7% per year for the EU25 in the P&M scenario, while the RES-share of the new member states is speeded up by about 10% per year, against 1.2% per year for the EU25 in the BAU scenario and about 3% for the new member states (see also 4.2).

- o Increased use of CHP production:

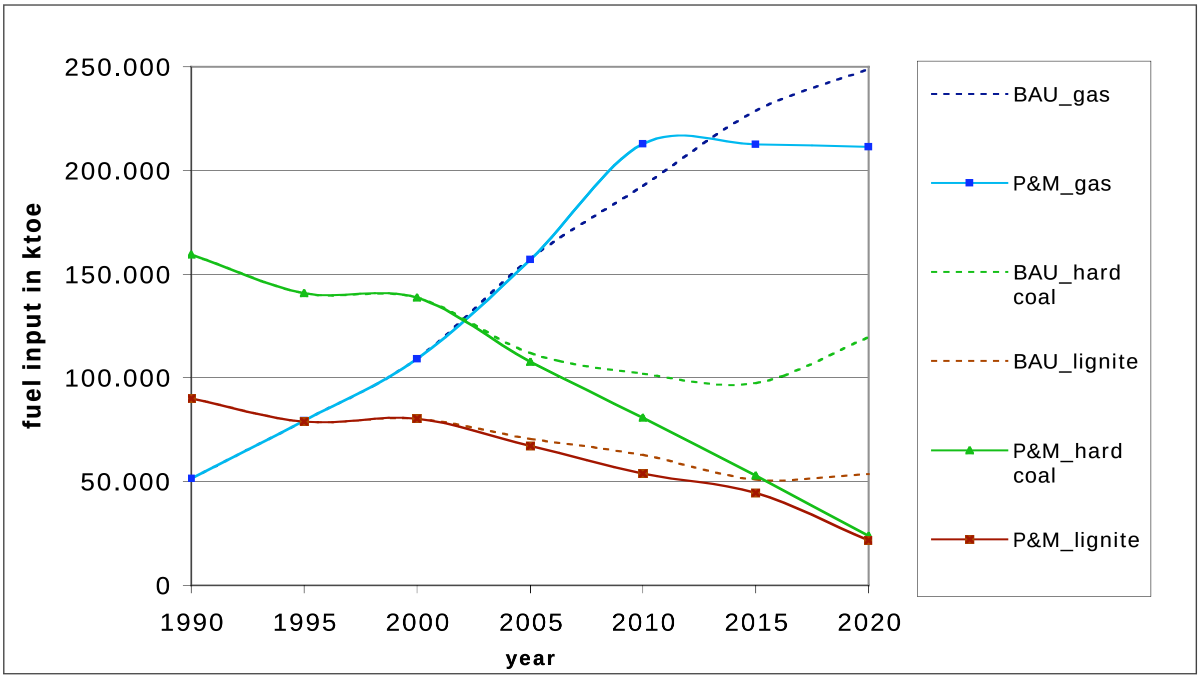
  The P&M scenario contains an ambitious CHP strategy which achieves a 3.5% per year increase of the CHP share of total electricity generation for the EU25 (from 14% in 2005 to 23.5% in 2020), despite a decreasing CHP share among the new member states between 1995 and 2005 (from 24.7% to 19.7%).

  This will be achieved primarily by a higher electricity to steam ratio of new gas-fired CHP plants and increased use of decentralized CHP, assuming that heat generation in boilers is substituted in a step-wise manner by CHP steam generation. (In the P&M scenario, by 2010 15% of the boilers' steam production is substituted by CHP, rising to 35% by 2020). In the EU15, 45% of CHP will be produced by biomass by 2020, 50% by gas, and 5% by coal. In the NMS the share of coal will decline to about 20%, with natural gas and biomass contributing 40% each.

- o Fuel switch to low-carbon fuels, in particular natural gas:

The expected fuel switch will lead to a high penetration of combined-cycle gas turbines (CCGT) that operate using natural gas, resulting in a decrease in the amount of hard coal and lignite-fired power plants. Figure 8 illustrates this change in the P&M and BAU scenarios. Differing from the BAU scenario, this current trend does not stop in the P&M scenario, but is prolonged until 2020. The share of natural gas increases in both scenarios. However, in absolute terms in the P&M scenario it remains at a constant level from 2010 onwards as a result of electricity savings and an increasing share of renewable energies. In the BAU scenario, meanwhile, the consumption of natural gas constantly increases until 2020.

Figure 8: Fossil fuel use in power generation, BAU versus P&M Scenario



Source: own calculation

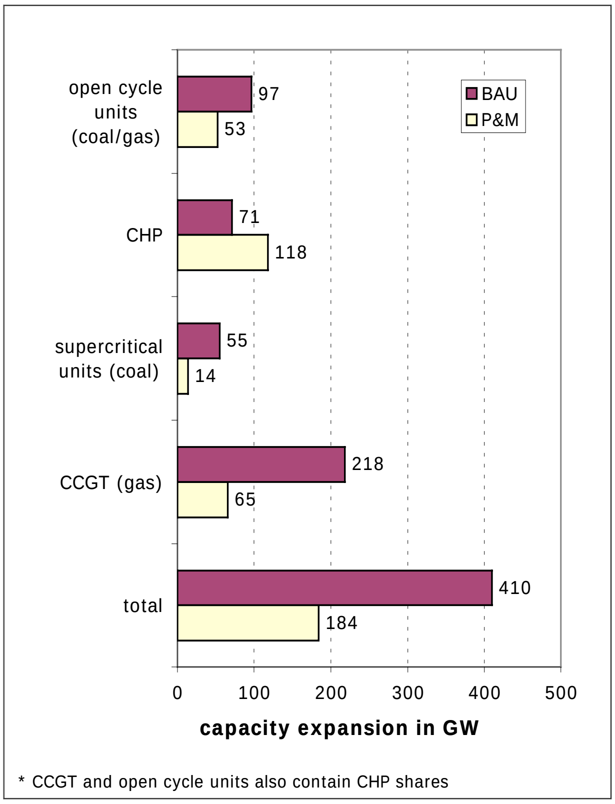
- o Supply side efficiency improvement:

  In the P&M scenario the efficiency of thermal power plants rises by 1.5% per year for the EU25, from 39% to 49% (2005-2020), compared to an increase of only about 1.3% per year, to 47%, in the BAU scenario. This efficiency improvement will be achieved by the fuel switch to gas-fired CCGT with high electric efficiency, the substitution of old coal-fired cogeneration plants by new gas-fired ones with a higher electricity to steam ratio, a general preference for best available technology for new power plants, and specific research & development.

Another option to improve the efficiency of electricity production is the retrofitting of existing old power plants; for example, replacing steam turbines, optimization of the condenser side or introducing a heat recovery system. In general, retrofitting of thermal plants improves the efficiency by up to 2 percentage points and leads to an extension of the plant's lifetime.

However, as in the P&M scenario a large proportion of power plants will be substituted by CHP and renewable generation, no active strategy to retrofit old power plants is assumed. Compared with the BAU projection, the P&M scenario includes cutting new fossil power plant investment by 50% and no new nuclear capacity. Conversely, investment in CHP capacity is nearly doubled compared to BAU.

Figure 9 New and reinvested capacity of thermal power plants in the EU25 (2005-2020)

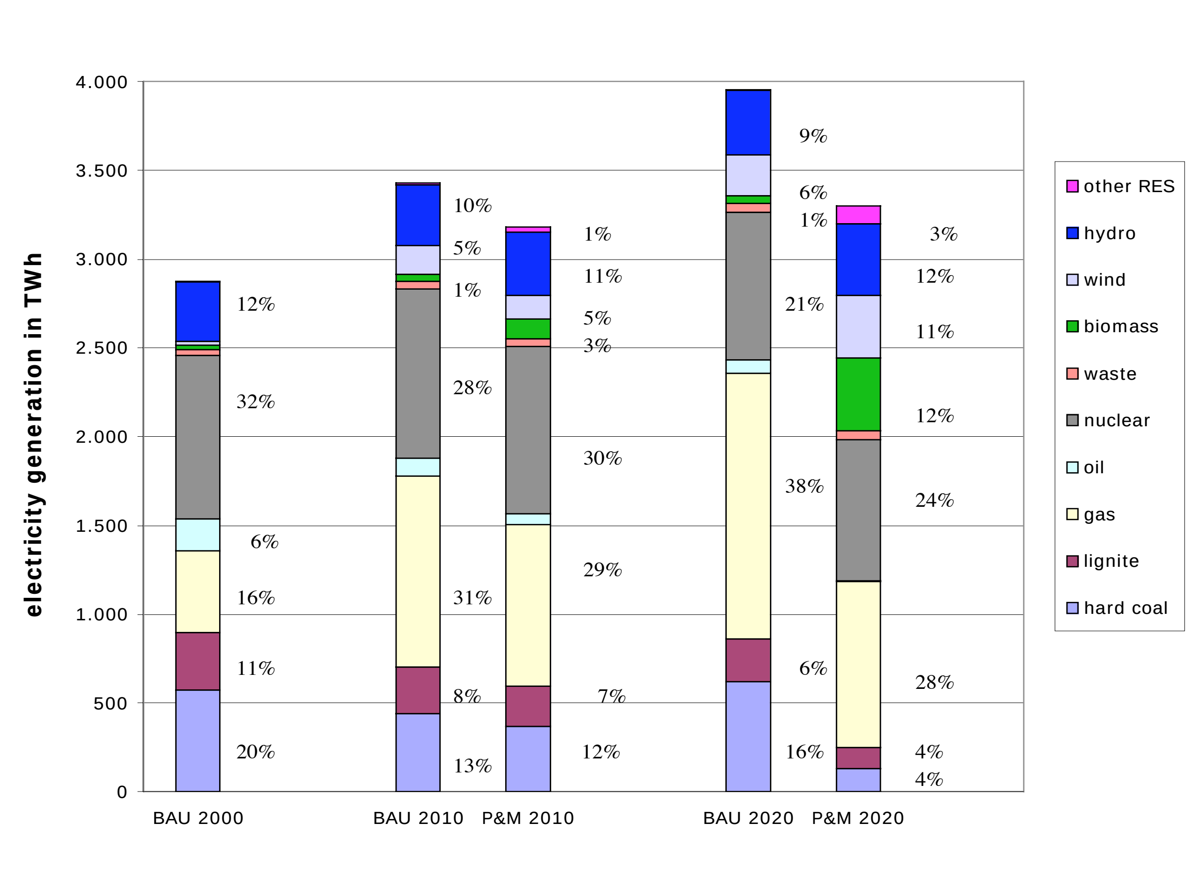


Source: own calculation

Summing up, the share of carbon-intensive fuels (mainly coal) decreases in favour of natural gas, biomass and wind energy in both scenarios (see Figure 10). In the P&M scenario, however, this shift is achieved much faster due to active demand-side measures that mitigate further increasing consumption, a stronger ETS, and to accelerated investment in renewable electricity generation (mainly biomass, wind and other renewables). With regard to electricity generation from nuclear energy, the P&M scenario assumes a moratorium on new nuclear power plants. However, with decreasing total electricity generation in the P&M scenario, the share of nuclear energy is slightly higher than in the BAU scenario.

Under the strategies outlined in the P&M scenario, a 56% reduction of CO_2 emissions between 2020 and 1990 levels is achieved. Figure 11 illustrates the CO_2 emissions from electricity and steam generation by fossil fuel. In the BAU scenario it is expected that gas substantially increases its share of emissions from power generation. Emissions from coal-fired plants, on the other hand, are expected to decrease only slightly, which leads to an overall increase of CO_2 emissions from power production to about 1995 levels. In the P&M scenario, however, fossil-fuelled electricity generation is reduced substantially, leading to slightly lower emissions from natural gas and to a 79% reduction in the emissions from coal.

Figure 10: EU 25 electricity generation in TWh

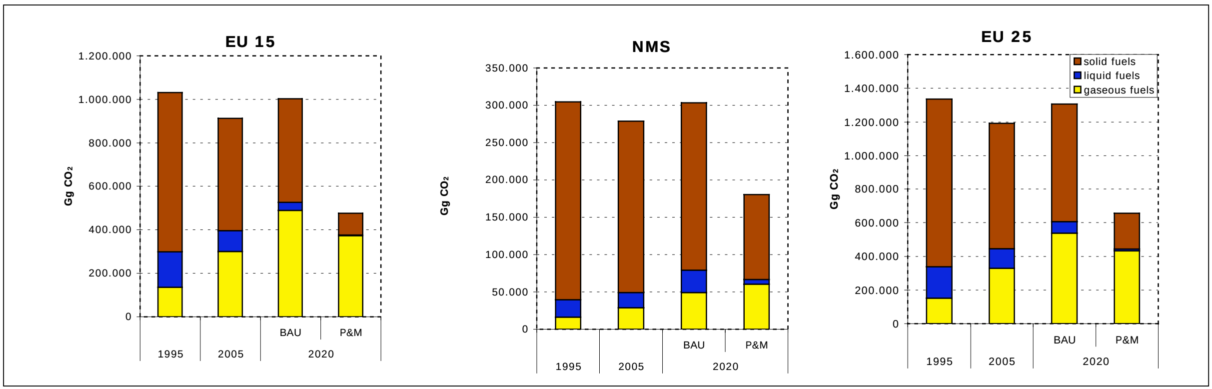


Source: own calculation

Micro-CHP

The increased use of cogeneration plants includes also an active market introduction of micro-CHP. Stirling engines, small internal combustion engines and fuel cells contribute to the electricity and heat supply for single houses, apartment blocks or housing areas. Today, small internal-combustion engines are the most established technology in the CHP sector. Units smaller than 10kWel that can be integrated into single households for combined heat and power supply are already available on the market. New on the market are external-combustion engines like Stirling or steam engines which produce lower emissions (catalytic combustion of natural gas) and have better characteristics where noise, vibrations and maintenance intervals are concerned. Another great advantage of external-combustion engines is their multi fuel-ability (especially biomass fuels like pellets, plant oil, wood, etc.). By actively promoting these – close to market – technologies, CHP has the potential to rapidly increase. In the meantime, more conventional CHP options can play an important bridging role while the necessary small-scale supply structures are built up. At a later stage, fuel cells will also become available on the market. Finally, micro gas turbines could be of considerable interest to the commercial sector, especially when operating with biogas.

Figure 11: CO_2 Emissions in the power sector, comparison of BAU and P&M scenarios



Source: own calculation

4.2 Renewable energy supply

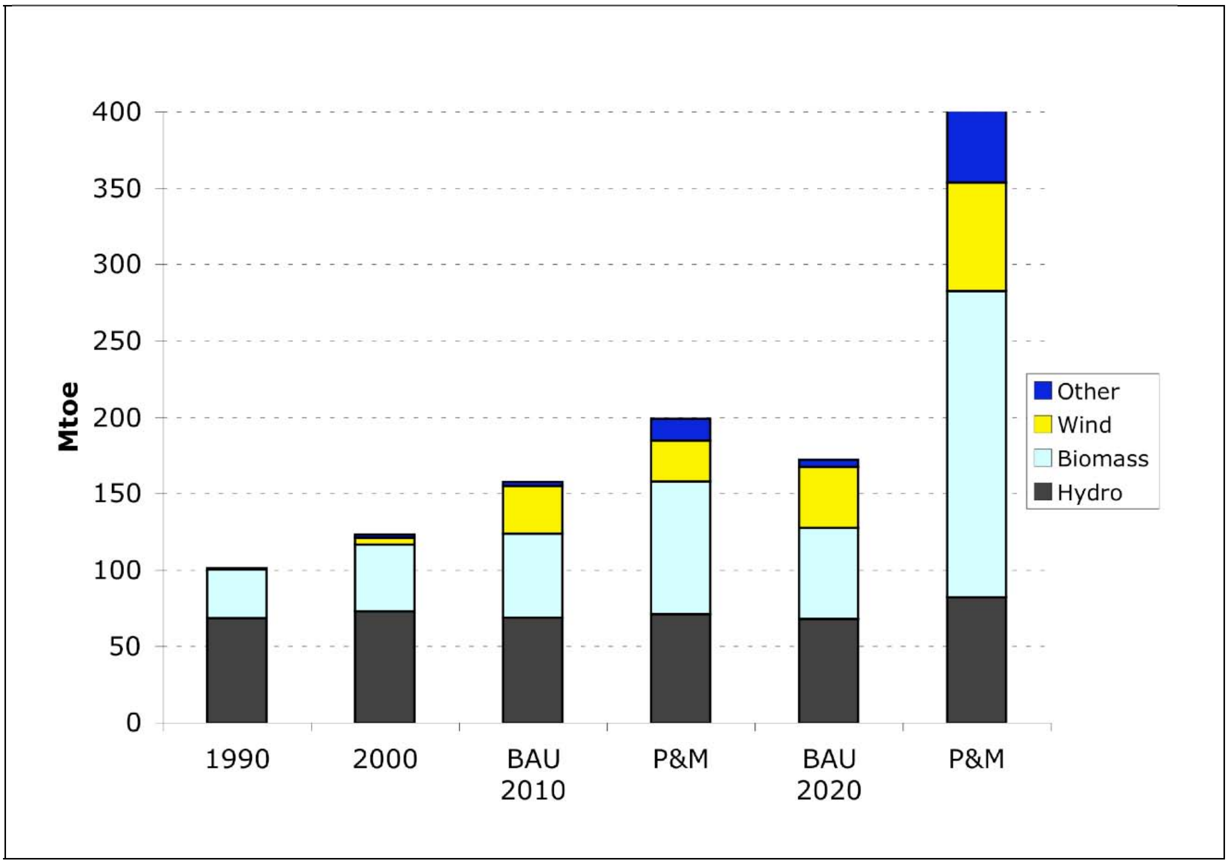
An expanded use of renewable energy sources is an important strategy for a sustainable energy system. Under BAU conditions the share of RES of gross inland energy consumption will reach 9.3% (176 Mtoe) in 2020, with a 1.8% growth rate from 2000 to 2020 (cf figure 12).[11] In terms of electricity generation, RES are expected to account for 68.4 Mtoe and 9.4% of the total fuel input (728 Mtoe) by 2020. In the transport sector, biofuels will meet 3.3% of road transport final energy demand by 2020 – far below the current 5.75% EU15 target for 2010. In the BAU scenario, 39.6% of total RES primary production results from hydro (68.1 Mtoe), while biomass accounts for 34.7%, wind up to 23.1%, and other RES totalling 2.5%.

In the P&M scenario, by 2020 RES will account for 402 Mtoe of EU25 gross inland consumption, with a share of 24.5% of primary energy supply and an annual growth rate of 6.10% (from 2000 to 2020). The most important RES in the P&M scenario are biomass (49.8% of total RES), hydro (20.4%) and wind (17.7%). Other RES such as geothermal, tide and wave, solar thermal, and photovoltaic plants will account for 12.1% of total RES and have the fastest growth rate (+20.2 % pa), but biomass (+7.9% pa) and wind (+13.5% pa) contribute the highest total amount of energy generated. Compared with the BAU scenario, by 2020 the P&M scenario will have provided three times the amount of biomass, one and half times the amount of wind energy, and a tenfold amount of other RES. Each of these sources, of course, has environmental and social impacts that should be addressed through strong quality standards.

11 According to the Eurostat Convention, the primary energy production of wind, solar and photovoltaic energy sources is calculated with a conversion efficiency (primary to final energy) of 100%, whereas the conversion efficiency of nuclear power generation is assumed to reach 33%. For this reason the share of renewable energies is relatively low in primary energy balances compared to nuclear energy. According to the substitution principle, the primary energy production of wind, solar and photovoltaic energy sources is calculated with a conversion efficiency (primary to final energy) of the average conventional power generation in the covered area. Applying this approach, the share of renewable energy sources of primary energy is higher compared with Eurostat. In this report the substitution principle is applied.

In the P&M scenario, RES will be used mainly in the transformation sector for electricity and combined heat and power production (73.1%), in the residential sector for heat (solar) and photovoltaic electricity generation (13.5%), in the transport sector as biofuels (9.5%), and in other sectors (3.9%).

Figure 12: RES Primary Production in EU25

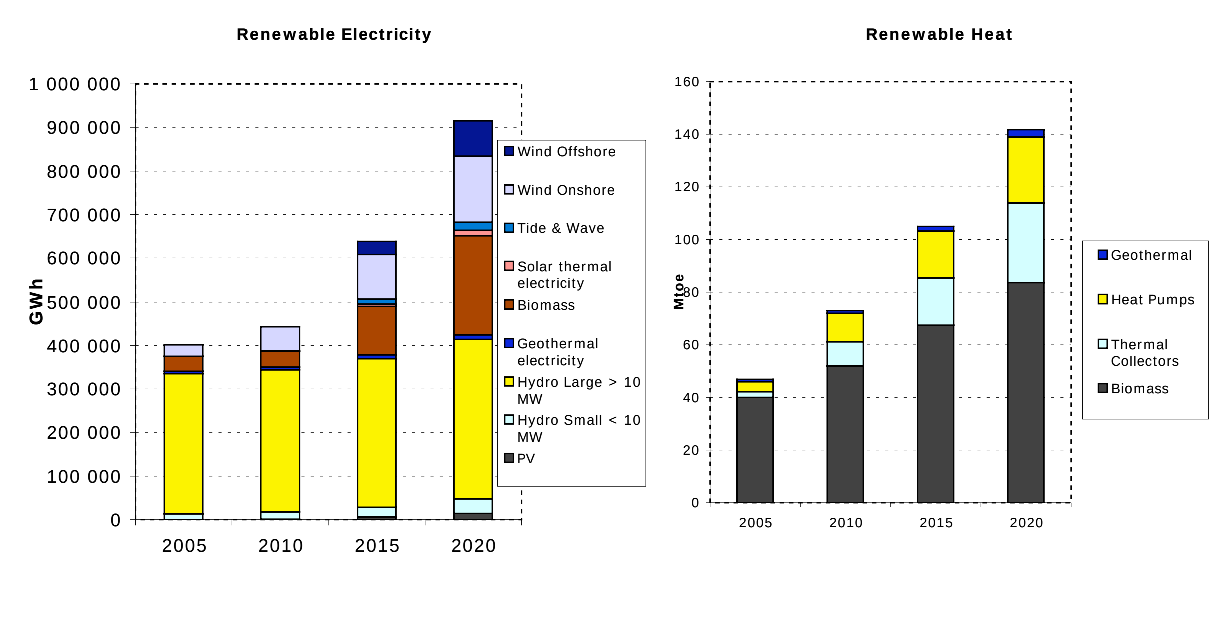


Source: Own calculations based on Mantzos (2003) and European Commission (2004c)

Renewable electricity and heat generation

In the P&M scenario the share of renewables in electricity production increases from 13% in 2000 to 38% in 2020 and amounts for 1273 TWh, which is in line with the targets of the EU-RES-Directive of 22% renewable electricity generation by 2010, and protracts this development until 2020. This is an ambitious strategy compared to the BAU scenario, in which by 2020 renewable energies generate only 16.5% of electrical power generation. The main differences between the P&M and BAU scenarios are an increased share of biomass from 0.9% in 2000 to 12.4% in the P&M scenario against just 1.1% in the BAU scenario, and a doubled expansion rate of wind power from 0.8% of EU25 electricity generation in 2000 to about 10.8% in 2020 against 5.9% in the BAU scenario. Other renewables such as photovoltaics and geothermal energy will contribute 3.1% of electricity production in the P&M scenario in 2020 (see Figure 13). The growth rate of renewable heat will reach 11.7% per year between 2000 and 2020, leading to 142 Mtoe of renewable heat generation by the end of this period. The main potentials to be exploited for this development are:

Figure 13: Renewable Electricity and Heat Generation in EU25



Source: Own calculations based on Mantzos (2003) and European Commission (2004c)

- Capacity expansion and efficiency improvements due to retrofitting of existing hydropower plants (+1% pa, 2005 to 2020). In contrast to the BAU scenario, the generation capacity of small hydroplants remains almost at 2005 levels in the P&M scenario due to environmental concerns.
- Installation of 102 GW onshore wind turbines (with an average of 2000 full load hours) and 51 GW offshore (with 3000 full load hours). By 2010, offshore wind farms will have reached an installed capacity of 10.3 GW, with about 4 GW added annually until 2020. Onshore wind generation capacity is expected to almost double between 2005 and 2010, from 27.5 GW to 51 GW, and again between 2010 and 2020. Wind electricity generation will reach 355 TWh in 2020, of which 203 TWh will be generated by onshore plants and 152 TWh offshore.[12]
- About 100 Mtoe of biomass (solid biomass, biogas and biowaste) will be used in the transformation sector to generate heat and electricity in CHP plants. A substantial increase in CHP generation capacity will lead to a biomass electricity generation of around 407 TWh in 2020.

Focus on Biomass

With a total supply of 200 Mtoe, biomass will account for almost half of the total RES used in the P&M Scenario in 2020. Around 13.9% of the total biomass is used in the household

[12] The total mid-term potential of wind electricity generation in EU25 amounts to 544 TWh, of which 287 TWh are located onshore and 257 TWh offshore (European Commission 2004b). Due to the remaining uncertainties in the development of offshore wind farms, their contribution to electricity generation was projected here as a conservative estimate of just 153 TWh in 2020. However, if the market develops faster, a higher offshore wind energy potential could be realized by 2020 resulting in a considerably higher share of renewable energies in electricity generation and in primary energy production (see also the recent publication of the European Renewable Energy Council which proposes 444 TWh of electricity generated from wind turbines in 2020, EREC 2005).

sector, 1.7% in the tertiary sector, 4.3% in the industrial sector, and 18.8% in the transport sector, while the bulk (61.3%) is converted by the transformation sector into heat (972 TWh_{th}) and electricity (407 TWh_{el}).[13] Biomass in electricity generation faces a 17.5% growth rate per year between 2005 and 2020, driven mainly by an ambitious new CHP generation capacity building programme. The biomass used for electricity generation consists of solid biomass (65.5%), biogas (25.5%, mainly usage of manure gasification; see also chapter 4.8.2), and biowaste (8.9%). The yearly growth rate of biomass in decentralized heat generation is 7.7%, leading to a doubling by 2020. The P&M scenario assumes that 80% of the EU biofuel mid-term potential (European Commission 2004b) will be achieved, resulting in a biofuel demand of 37.6 Mtoe (BAU: 12.6 Mtoe). This leads to a 14.5% share of biofuels in total road transport final energy demand.

As a natural resource, biomass production in the EU is limited by the availability of agricultural and forestry land, as well as nature conservation land, and competition with the land used for food production (EEA 2004b). Besides the use of biomass in the sustainable energy strategy, it has a role to play as a renewable material resource for industry. The question of where and how best to use the potential of – mainly solid – biomass and how to solve the potential competition with food production is still open and subject to further studies (cf. Nitsch *et al.* 2004). In the P&M scenario the import of renewable energies is not taken into account. Biomass import (e.g. biomass ethanol from Brazil) could increase the available biomass in Europe markedly. Nevertheless, the economic viability and ecological efficiency of renewable energy imports needs to be analysed in greater detail.

Other renewable energy sources

Besides established RES with high amounts of already working generation capacities like biomass, hydro and wind, there are other promising RES technologies with significant growth rates but – for the next decades – limited total share:

- Tide and wave electricity generation is not expected to contribute to electricity generation before 2010. After 2010, remarkable growth rates of around 12% per year are expected. In 2020, marine energy will reach a 2.5% share in renewable electricity generation.
- Photovoltaic electricity generation, together with solar thermal electricity generation, has the highest annual growth rates (above 23%) in RES electricity generation. However, its share of around 2% of total renewable electricity generation will remain limited in 2020.
- Geothermal energy will be used for both electricity and heat generation, with the highest potential located in Italy, which has high-enthalpy geothermal resources (90% of all EU25 geothermal electricity generation and 43% of all EU25 heat generation potential in 2020).
- Heat pumps and solar thermal heat generation plants will each reach an almost 20% share of total RES heat generation in 2020, with high growth rates in the coming 15 years.

[13] The level of biomass power generation in the EU25 is comparable to the results in the WWF BioPowerSwitch! report (Bauen *et al.* 2004).

- Solar and wind power generation in North Africa could be imported to Europe using the Global Link concept of a power transport network between Europe and North Africa. This increases significantly the renewable electricity generation potential in Europe, but is not considered here owing to the high level of uncertainty surrounding the realization of this concept within the timeframe of this study.

To sum up, through an active policy and ambitious targets, RES can contribute to an overall CO_2 emission reduction of around 600 Mt CO_2. This is almost one-third of total emissions reduction in the P&M scenario compared to the BAU scenario. There will be 115 Mt CO_2 emission reduction in the transport sector, 280 Mt CO_2 emission reduction in the transformation sector, and 205 Mt CO_2 emission reduction in the household, tertiary and industrial sector resulting from RES in 2020. Furthermore, domestic renewable energies together with energy savings can stabilize EU import dependency at about current levels. For this reason a high share of RES reduces considerably the risk of energy supply shortages and/or price shocks in Europe.

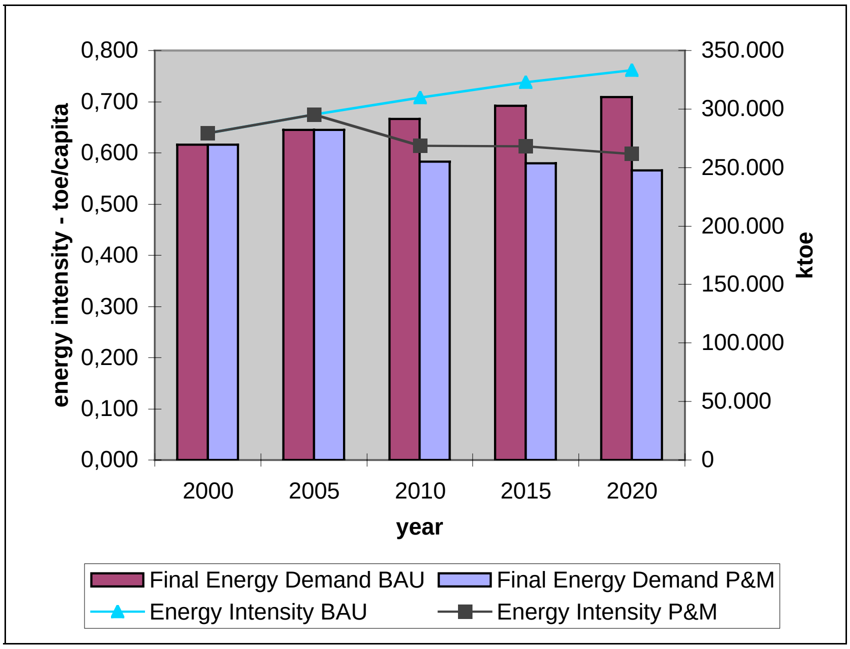
The cost effectiveness of the implementation and use of renewable energies can only be fully evaluated in the long term (by 2050), viewed against conventional energy supply options and underlying climate change and GHG reduction targets. In a study analysing the utilization of renewable energies in Germany, Nitsch *et al.* (2004) pointed out that from 2030 onwards renewable electricity generation is likely to be cheaper than conventional zero emission electricity generation (using carbon capture and storage technologies). With efficiency improvements and decreasing costs, renewable electricity generation becomes economically favourable after 2030 and leads to lower economic costs than conventional power generation. The level of the price on carbon will also have an impact on the financial attractiveness of renewables. But until 2030 the technological development and market implementation of renewable energies needs to be supported strongly for a successful market penetration. The average additional costs (from 2000 to 2050) of renewable energies amount to 2% of total costs of the whole energy supply chain (Nitsch *et al.* 2004).

4.3 Residential sector

The residential sector was responsible for 26% of total final energy demand in the EU25 in 2000. Although this share is expected to fall to 25% in 2020 in the BAU scenario, absolute figures are still growing, as Figure 14 shows. The reasons for this development are an increasing number of households and growing living space per inhabitant, as well as increasing living standards, connected to a level of catch-up demand for household appliances in the new member states. However, there are huge and cost-effective energy saving potentials, both for electric appliances and lighting as well as for residential heating. Energy savings of 20% as against the BAU level are possible by 2020 if corresponding measures are implemented. This equates to a reduction in demand of more than 2% as against 1990. Furthermore, per capita-related energy intensity will decrease faster in the P&M scenario than in the BAU case, reaching a value of 0.566 toe/capita in 2020 (as against 0.710 in the BAU case).

The main measures for improving energy efficiency are discussed for electric appliances, space heating and water heating.

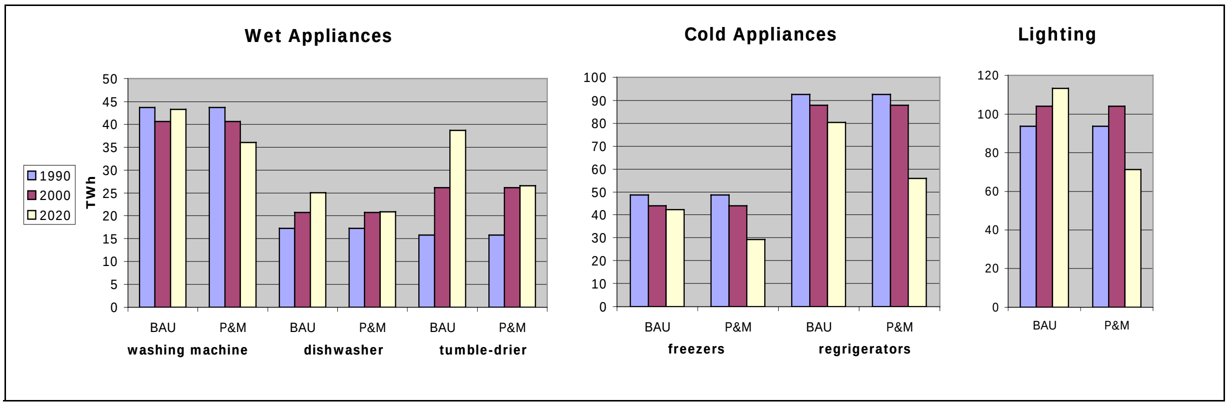
Figure 14: Final energy demand and energy intensity in the residential sector



Source: own calculations, BAU based on Mantzos et al. (2003)

For domestic electric appliances the P&M scenario assumes that today's best available technology will be the average fleet value in 2020. It is also assumed that three-quarters of all electric light bulbs are substituted by compact fluorescent lamps. These two factors would lead to an electricity demand reduction in residential buildings of more than 36% as against BAU. Figure 15 shows the outcomes of this approach for wet and cold appliances and for lighting – among the biggest electricity consuming products. A good part of the energy savings is compensated by higher penetration rates of appliances in households though.

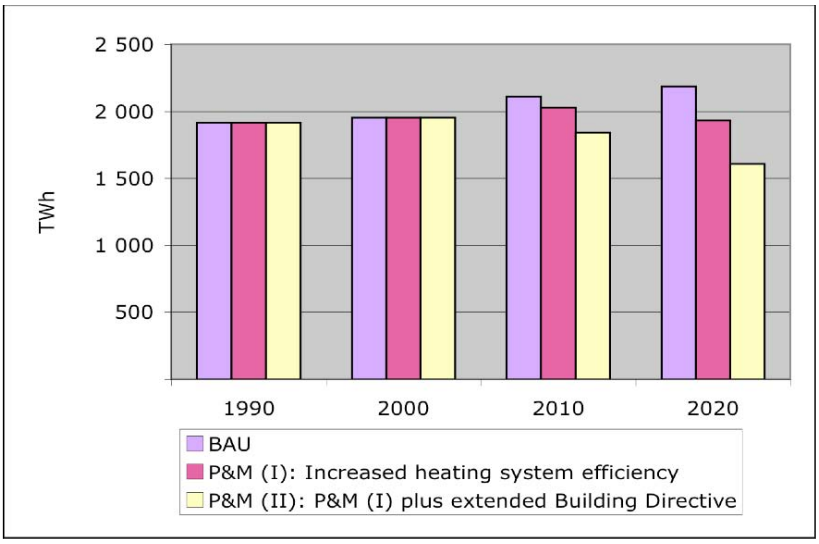
Figure 15: Electricity consumption of wet and cold appliances and lighting in GWh (EU25)



Source: own calculations based on CECED 2001; ECI et al. 1998, 2000

Heating, including space heating, water heating and cooking, accounts for about 89% of total final energy demand in households in the EU15. (For our calculation this figure is also assumed for the NMS.)

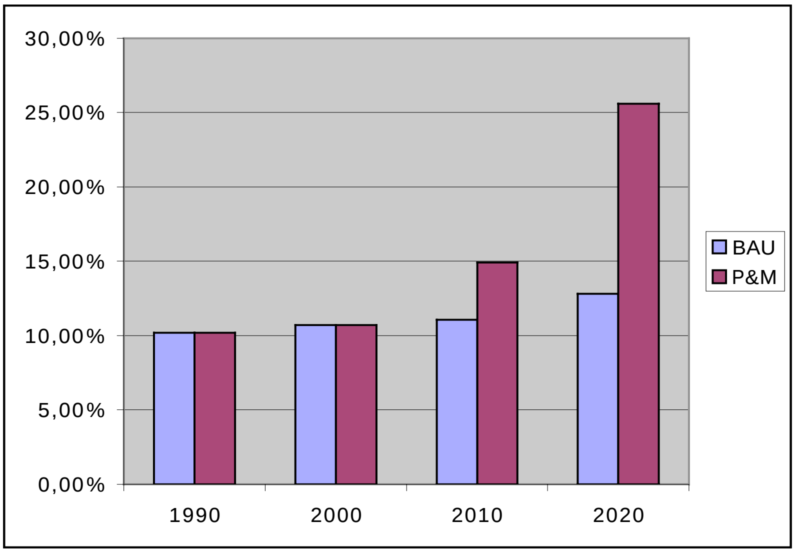
Figure 16: Strategies for reduced space heating energy demand (EU25)



Source: Own calculation based on BRE et al. 2002, ECOFYS 2004

A huge potential for energy savings is observed in residential space heating. Two main strategies can be identified: Firstly, strengthened efforts concerning the insulation of buildings and building components such as windows, roofs and the entire building envelope, going beyond the current provisions of the EU Directive on the energy performance of buildings. Secondly, an increase in efficiency of the entire heating system, combined with a fuel switch to gas, biomass and solar, and a further increase in district heating and efficient cogeneration of heat and power.

Figure 17: Share of renewables in residential space and water heating in the EU25



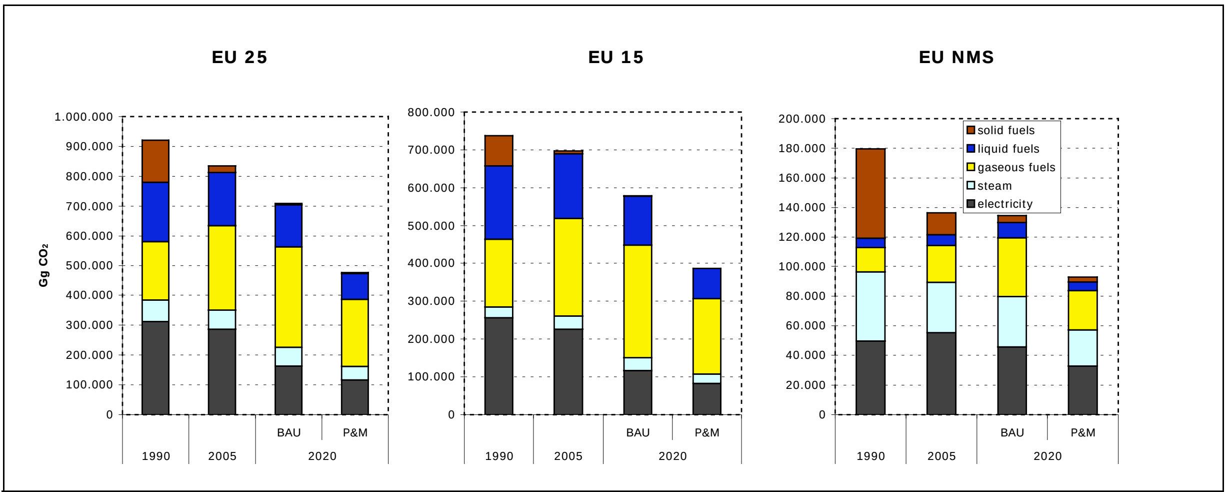
Source: own calculations

Improving the efficiency of the space heating system – i.e. heat generator (boiler), heat emitter (e.g. radiator) and control of the system – by 10% as compared to the BAU scenario would lead to a reduction in energy demand of more than 11% by 2020 in the EU15 (cf. Iles 2003; BRE *et al.* 2002). A further 15% reduction can be achieved by the extension of the EU Directive on the energy performance of buildings to all new buildings and those of the existing stock that are undergoing considerable reconstruction (ECOFYS 2004, see Figure 16). The relative saving potential for the new member states is estimated to be even higher due to an older average building stock and – on average – poorer performance of heating systems and insulation.

Water heating is responsible for about 25% of total energy demand in residential houses. For the P&M Scenario, a 10% higher efficiency as against BAU is feasible through more efficient heating systems (ECI *et al.* 2001). At the same time solar thermal heating systems can achieve a substantial share of water heating (up to 36% in the EU25). This means that by 2020 more than 50% of all households will have solar-heated water[14]. (cf. Figure 17).

Figure 18 presents the outcomes of the policies described in terms of CO_2 emissions. In the P&M scenario savings of more than 48% can be achieved in the EU25 against 1990 levels and more than 32% as against BAU. These reductions are achieved by higher energy efficiency, increased use of renewable energies, and reduced emissions from electricity generation.

Figure 18: CO2 emissions of the residential sector by final energy (including heat and electricity)



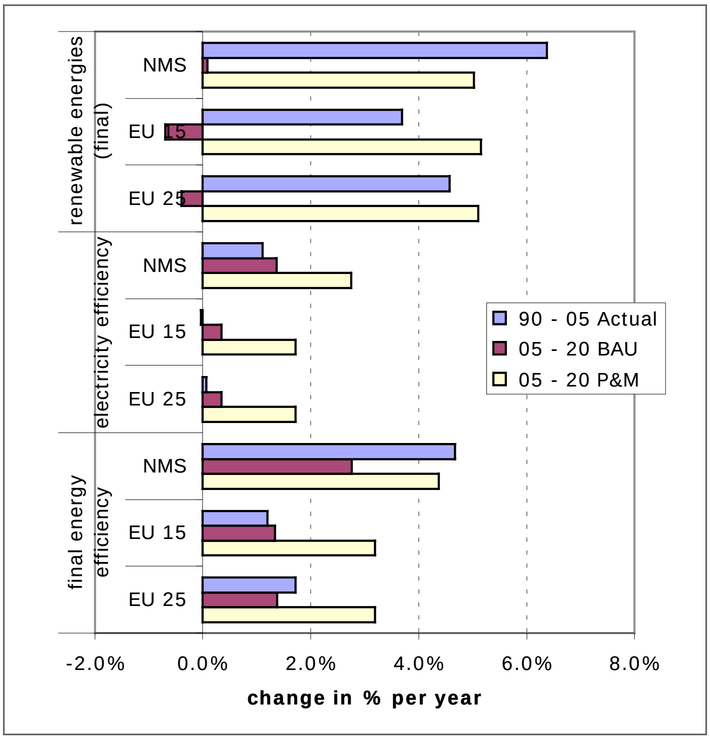
Source own calculations; BAU based on Mantzos et al. (2003). Note: emissions from steam and electricity are indirect emissions from power and district heating systems.

14 The average share of solar-heated water will thus be about 70% per household using solar collectors for hot-water generation.

4.4 Tertiary and Services sector

The tertiary and services sector (which also includes energy consumption in agriculture[15]) represents most of the economic activities of the EU. It includes public buildings, shops, warehouses, office buildings and all agricultural premises. In terms of energy consumption it is the smallest demand sector in the EU. However, growth rates of final energy demand are projected to be second only to the transport sector under BAU conditions. High increases are expected in particular for electricity consumption due to higher demand for office and multi-media equipment, air conditioning, cooling and lighting.

Figure 19: Improvement of energy efficiency and use of renewable energies, tertiary sector



Source: own calculations; renewable energies (final): only those renewable sources counted that are directly used in the sector (e.g. biomass, solar thermal);

The galloping final energy demand in the tertiary sector is driven by both the increasing economic importance of this sector and the rapidly increasing quantity of energy-consuming equipment. In the BAU scenario energy-efficiency improvement in the sector is expected to fall behind current levels, mainly because the EU new member states will not be able to maintain their rapid increases in efficiency and the EU15 will achieve only very slight improvements over past trends. With regard to electricity efficiency, almost no improvements have been made since 1990 and in the BAU scenario electricity efficiency increases only slightly, by 0.4% per year. The share of renewable energies is actually expected to decrease in the BAU in spite of rapid increases over the past 15 years.

In Table 1 a number of available technologies and options for the optimization and reduction of energy demand in the tertiary sector are listed. A wide range of these options has been analysed by the Wuppertal Institute in previous studies, based on available studies on energy-saving potentials in sectors and by technologies.

For the purposes of this study the energy-saving potentials compared with BAU trends have been extrapolated to the EU15 and the NMS by energy use and by fuels, as well as by electricity.

[15] Emissions from agricultural energy use are included in this sector. Other emissions from manure management etc. are discussed below in a separate chapter.

Table 1: Energy-efficiency measures and technologies in the tertiary sector by energy use

Energy use	Efficiency measures/technologies	Average savings vs. BAU
Space heating	Lo- energy buildings/offices for new developments Retrofitting of existing buildings (low-energy standard) Optimized heating technology (condensing boilers, district heating, biomass, solar heating)	32%
Hot water	Demand reduction by water-saving appliances (washing machines, dishwashers, showers etc.) Optimized heating technology (see above), solar-heated water	17%
Cooling/freezing	Improved placement of appliances (e.g. shaded), installation of doors and shutters, installation of high-efficiency appliances	22%
Lighting	Electronic ballasts, better daylight use in new and retrofitted buildings, retrofitting of existing installations, increased use of compact fluorescent lamps (CFL), demand-oriented controls, introduction of LED technology in warehouses, shops etc.	13%
Air conditioning	Demand-oriented control and regulation, passive/natural cooling systems in new buildings, regular maintenance and control of existing systems, integrated planning (prevention of high thermal ballasts), solar cooling systems	17%
Electronics	Reduced standby consumption, increased use of mobile technology, LCD screens	28%
Cooking	Improved ovens and kitchen ware, induction technology, substitution by natural gas	23%
Motors	Electronically controlled motors, improvement of small standard motors, permanent magnet motors, demand reduction by optimization of processes (e.g. control of heating systems)	14%
Process heat	Process optimization, insulation, use of waste heat	23%

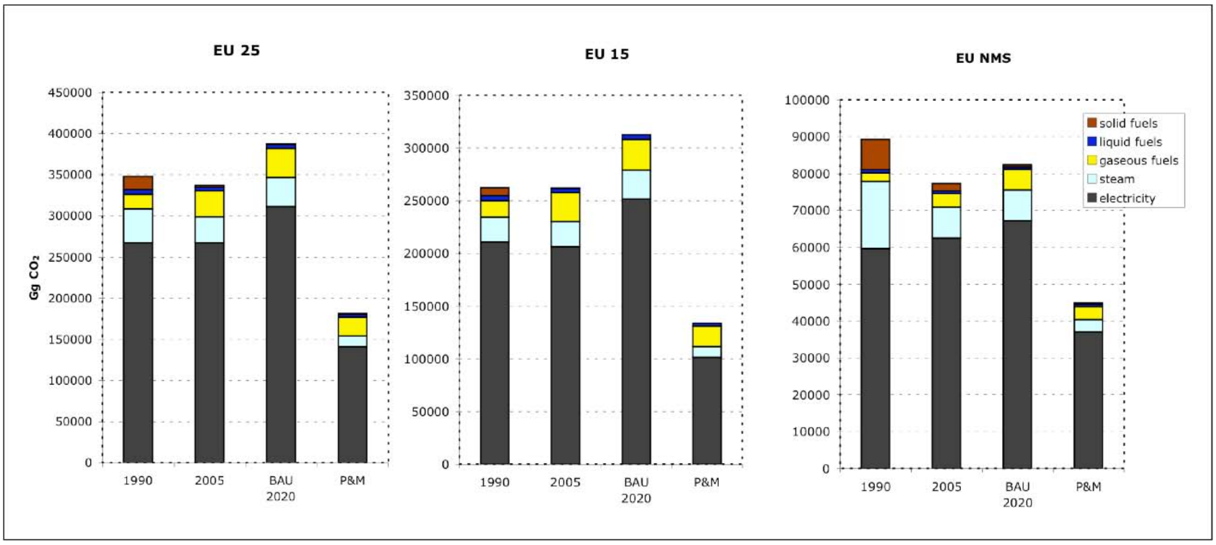
Source: Wuppertal Institute 2005; Lechtenböhmer *et al.* 1999; Cremer *et al.* 2001

By exploiting about 80% of the cost-efficient savings potentials of these technologies and solutions, energy-efficiency improvements – which are expected to develop rather slowly at just 1.4% per year in the BAU-scenario – can be more than doubled to about 3.2 % per year in the P&M scenario. Electricity demand-side efficiency improvement rate will be speeded up to 1.7% per year.

Overall this means that CO_2 emissions from this sector are bound to rise to about 102% of 1990 levels in the BAU scenario – in spite of a slight decrease up to 2005 which mainly occurred as a result of demand reductions in the NMS. In the P&M scenario, however, emissions can be reduced by 45% compared with BAU. This is achieved by:

- higher energy efficiency (about 23%);
- increased use of renewable energies (about 9%);
- reduced emissions from electricity generation (about 13% of all reductions in the sector).

Figure 20: CO_2 emissions of the tertiary sector by energy type

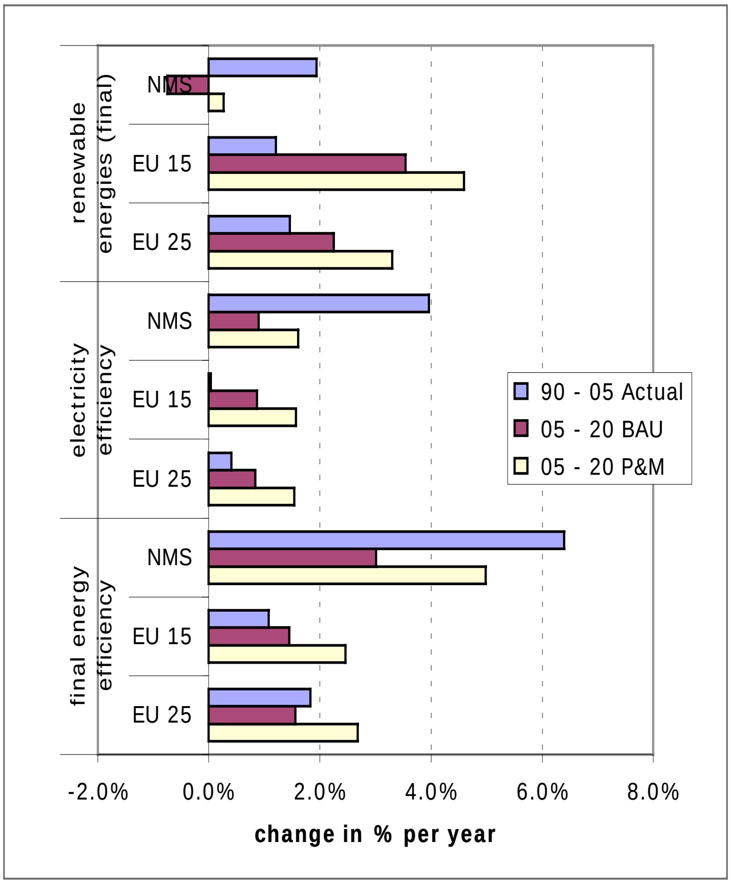


Source: own calculations (includes indirect emissions from district heating and power generation which are accounted for in the power sector)

4.5 Industry

With a final energy consumption of 310 Mtoe, industry accounted for about 28% of the EU's final energy consumption in 2000. This share will remain almost constant in the future under BAU conditions. This means that final energy demand will increase by 19% by 2020 in spite of a decrease of energy intensity from 185 toe to 131 toe per million Euro of value added. Sector CO_2 emissions are expected to rise again and reach about 86% of 1990 levels – almost 5% more than in 2005. In the BAU scenario the energy efficiency of industry will increase by 1.6% a year, which is slightly less than in the period 1990 to 2005 owing to a reduced rate of efficiency in the NMS but increased efficiency improvements in the EU15. The increase of electricity efficiency, however, is expected to double to 0.8% per year in the BAU scenario and the direct use of renewable energies will increase by 2.3% per year.

Figure 21: Improvement of energy efficiency and use of renewable energies in industry, comparison of scenarios



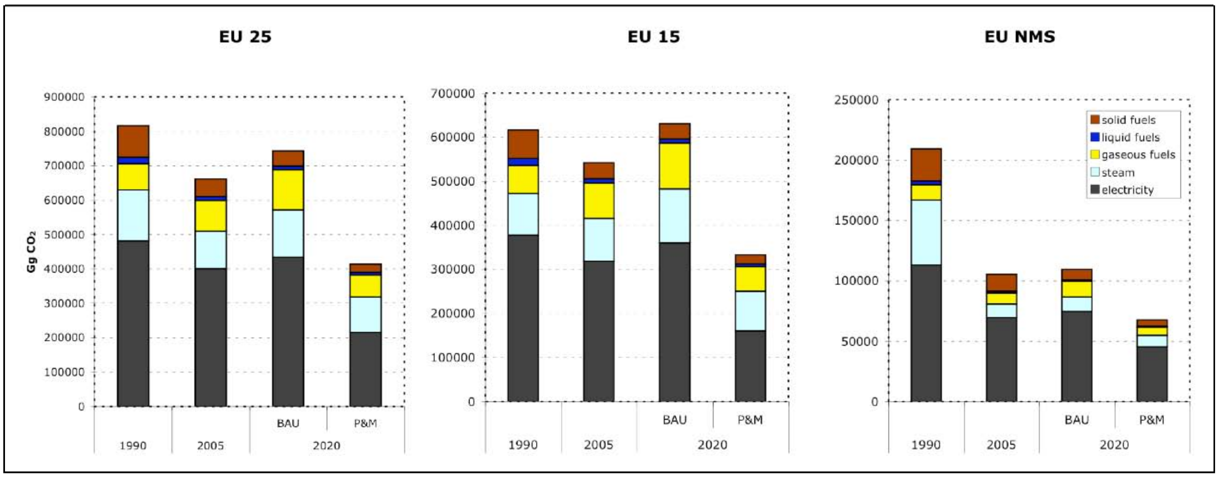
Source: own calculations

However, huge potentials for improving energy efficiency above BAU are available in the industry sector. Based on a number of studies made for Germany, The Netherlands and other European countries, respective potentials have been estimated by appliance for fuels and electricity.

Cremer *et al.* (2001) give a detailed description of 38 specific energy-intensive technologies which cover about 50% of the industrial energy demand in Germany. For these technologies they describe readily available savings potentials of about 16%. Bigger savings potentials are available when cross-cutting technologies, such as motor technology, pumps, fans, lighting, electronics etc. that are responsible for the other half of consumption, are taken into account. These technologies offer average savings potentials of 30% (cf. Fischedick *et al.* 2002).

Overall industrial energy efficiency can be improved by 1.1 percentage points above the BAU trend to 2.7% per year for final energy and to 1.5% per year for electricity. This improvement can be attained through cost-efficient savings in all industrial sub-sectors, placing emphasis on cross-cutting technologies such as energy-efficient electrical motors, modern lighting systems, process optimization etc. The remaining substantially higher energy intensity of the NMS in 2020 compared to the EU15 will then be mainly due to structural differences and lower value added. By adopting such an active energy-efficiency strategy, energy consumption by industry can be stabilized at about 5% below 2000 levels in 2020.

Figure 22: CO_2 emissions of industrial energy use by final energy type



Source: own calculations (includes indirect emissions from district heating and power generation which are accounted for in the power sector)

4.6 Transport

In the EU the transport sector is the fastest-growing sector in terms of final energy demand and CO_2 emissions. In addition to the problems caused by rapidly increasing energy demand, climate protection strategies are placing high dependence on imported oil products and this has raised concerns about the long-term security of oil supply. The transport sector accounts for around 70% of oil consumption in the EU25, a percentaqe which is slowly rising. Furthermore, the transport sector is causing increasing environmental damage beyond emissions of CO_2, including air pollution, congestion, erosion of landscapes and land use (INFRAS/IWW 2004).

In the BAU scenario a slight decoupling is expected between growth in passenger transport activity (1.8% pa) and growth in GDP (2.3% pa). Freight transport, however, increases by 2.2% pa, which indicates a growth parallel to GDP. Such rapid growth underlines the imperative for organizational and technological efficiency increases in the transport sector if overall emission reduction targets are to be met.

Passenger road transport

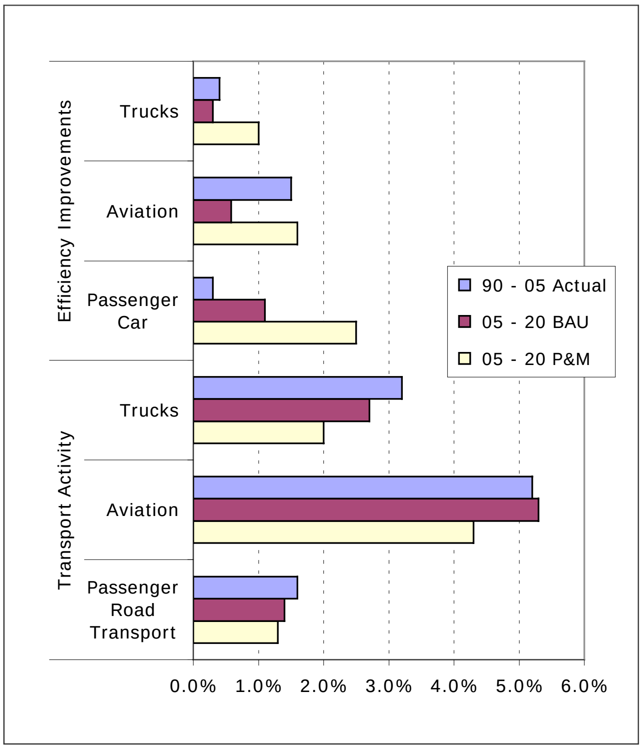
In the P&M scenario it is assumed that by pursuing active fiscal policies, regulatory and planning activities[16], such as road pricing and increasing energy prices, a moderate[17] reduction in demand growth in passenger road transport to 1.2% pa (against 1.3% in the BAU scenario) can be achieved. In effect, the annual passenger road transport activity per capita increases from 10,554 passenger kilometre (Pkm) in 2000 to 13,438 Pkm by 2020 in the P&M scenario (13,679 Pkm in the BAU scenario). Passenger train transport increases by 2.9% pa (BAU 1.5%) and public road transport by 1.7% (BAU 0.5%). This development

[16] The impact of single and local demand-side measures in passenger transport (e.g. local traffic management in London or Athens) is hard to extrapolate to the European level.

[17] Public acceptance of demand-side measures has to be considered carefully, which is why only moderate demand-side measures are assumed for passenger road transport in the P&M scenario.

implies a slight modal shift from private cars to train and public road transport, but the share of passenger train and public road transport of total passenger transport activity still remains limited (P&M: 15.7% in 2020).

Figure 23: Improvement of energy efficiency and development of transport activity



Source: Own calculations based on Mantzos (2003)

Substantial vehicle efficiency improvements account for almost 50% of all emissions reduction in the P&M scenario (cf Figure 23). The average specific emission target for the passenger car fleet is reduced to 100 g CO_2 per vehicle kilometre (vkm)[18] by 2020, accounting for emission reductions of 106 Mt CO_2 alone. In order to achieve this ambitious goal the average fleet emission targets for passenger cars have to be developed further. Until 2012 a target of an average 100 g CO_2/vkm for all new cars has to be adopted in Europe and implemented by car manufacturers, also taking into consideration vehicle stock turnover. Average fuel consumption in the new passenger car fleet amounted to 160 g CO_2/vkm in 2004, a decrease of 1.8% compared to 2003. A 3.3% annual improvement in fuel efficiency is necessary to meet the target of 140 g CO_2 /vkm by 2008.

Several technological options are already available to car manufacturers to enable them to meet these ambitious targets. These include hybrid cars, direct injection gasoline cars, a shift to diesel, lightweight structures, friction and drag improvements, engine improvements, energy management, and power train improvements (cf. Kageson 2005; Bates *et al.* 2001). According to Bates, a basic package of measures already existing in 2000 (engine friction reduction, aerodynamic drag reduction, rolling resistance reduction and zero brake drag; cf. Bates 2001, p 55) results in a CO_2 emission reduction of 10 g CO_2/ vkm. With advanced measures, such as using lightweight structures (-19 g CO_2/ vkm) or advanced gasoline direct injection (-36 g CO_2/ vkm), much higher CO_2 emission reductions are possible. A study commissioned by the UK Department for Transport highlights that it will be possible to produce, by 2020, an approximately 50% more efficient diesel-powered vehicle compared to a standard vehicle in 2003 (Ricardo 2003).

Road freight transport

By optimizing freight transport, transport logistics, road telematics, driver training and an intermodal freight transport system (a shift from road transport to combined road-rail and

[18] 100 g CO_2/ vkm equals about 4.3 l petrol/ 100 vkm and 3.8 l diesel/ 100 vkm respectively, which leads to a passenger car fleet average fuel consumption of about 4 l/ 100 vkm.

road-shipping transport), it is assumed in the P&M scenario that the growth of road freight transport can be slowed from 2.6% per year to 1.7%, resulting in an emission reduction of 55 Mt CO_2 in 2020 compared to BAU (cf. Bates *et al.* 2001).

In road freight transport, only very slow energy-efficiency improvements (0.3% per year) are expected in the BAU scenario, compared with 1.0% per year in the P&M scenario. A variety of technological developments can be implemented to enhance the specific fuel efficiency of trucks. These include engine improvements, weight improvements, aerodynamic drag reduction and reduced rolling resistance (Bates *et al.* 2001).

Aviation[19]

In the aviation sector ambitious policies and measures aimed at fuel efficiency improvements and logistics optimization are necessary to reduce specific GHG emissions. First, a slowing down of aviation activity by raising kerosene taxation, and support for alternative transport modes etc. at a rate of +4.0% pa instead of +5.4% pa in the BAU scenario; (cf. Scenes 2001, Airbus 2003) will result in emissions reductions of 34 Mt CO_2 in 2020 compared to BAU.

In the BAU scenario the emission factor for aviation covers only CO_2 emissions. According to the IPCC the emission factor for aviation triples when other emission effects (O_3 and CH_4 from NO_X, H_2O, contrails, cirrus clouds, direct sulfate, direct soot) are also taken into account (IPCC 1999). Recent research indicates that the global warming effect of contrails, O_3 and CH_4 is lower than estimated in the IPCC 1999 report, whereas the effect of CO_2 is higher (Schumann 2003; Wit et al. *2005). The GHG effect of cirrus clouds was not considered in the IPCC report due to very poor knowledge about either the effect or its warming impact. The total GHG effect of aviation is estimated to be three times higher than the effect of CO_2 emissions only. Consequently in the P&M scenario the share of GHG effect (including contrails and cirrus clouds) caused by aircraft rises to 35% of total transport sector emissions. In the BAU scenario GHG emissions, including non-CO_2 effects, amount to 588 Mt $CO_{2\ equivalent}$ and in the P&M scenario 417 Mt $CO_{2\ equivalent}$ by 2020 (CO_2 emissions: BAU 196 Mt CO_2; P&M 139 Mt CO_2). The consideration of other GHG (including contrails and cirrus clouds) in aviation amplifies the need for ambitious policies and measures to improve fuel efficiency, flight management, and the development of transport demand.*

In the aviation sector considerable fuel efficiency improvements have already been achieved in recent decades.

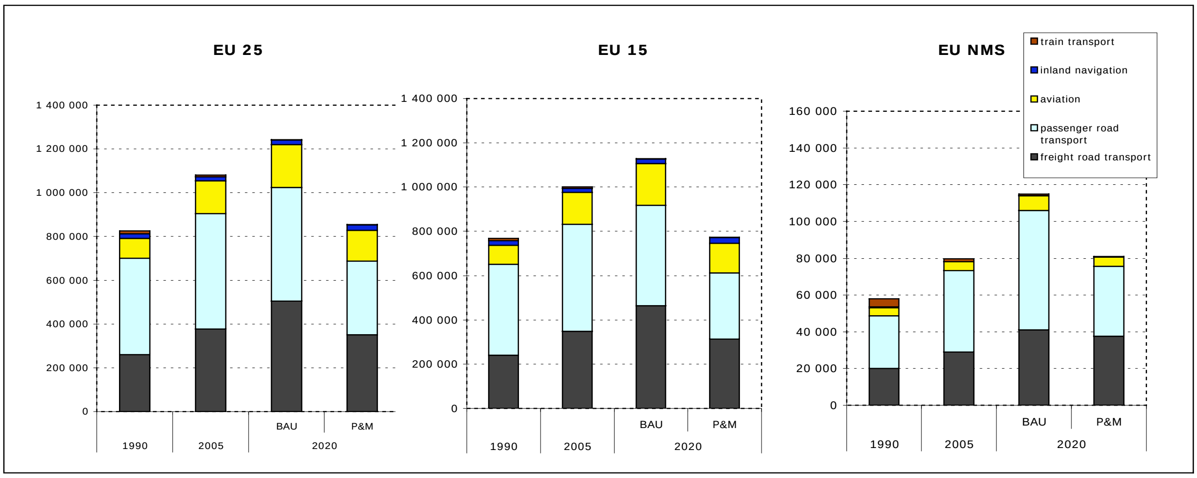
In the P&M scenario, emission reductions of 21 Mt CO_2 in 2005 rising to 63 Mt CO_2 in 2020 will result from a 20% (or 1.55% pa) reduction in average fuel consumption in aircraft (compared with 8% or 0.58% pa in BAU). A number of technological developments are available to further reduce aircraft fuel consumption, e.g. airframe weight improvements, extended flight control systems, full hybrid laminar flow control, geared fan engine or alternative liquid fuels (Lee 2003). The average age of the European aircraft fleet is relatively low compared to other regions of the world, due to the business practice of leasing. This means that aircraft stock turnover is quicker, enabling a faster penetration of new technologies. The main fuel efficiency improvements result from engine improvements, weight improvements (with a share of around 40% each) and flight management optimization (20%).

[19] The numbers for aviation cover domestic flights, flights between EU states and 50% of the flights from the EU to other countries.

Biofuels

New energy forms are assumed to remain insignificant in the transport sector in absolute terms despite rapid growth rates up to 2020. Only biofuels contribute notably to emission reductions in the transport sector. With a share of 14.3% (37.5 Mtoe) of road transport final energy demand, biofuels yield a 116 Mt CO_2 emissions reduction. However, whether such an extensive use of biofuels in the transport sector is the most sustainable solution given the limited biomass resources is still subject to debate. With regard to the environmental impact of biofuels resulting from use of land, growing of biomass, and fuel production, as well as their potential contribution to effective emissions reductions when converted by different technologies in different sectors into end use energy, biofuels still raise a number of questions and should be subject to further research (EEA 2004b).

Figure 24 CO_2 emissions in the transport sector



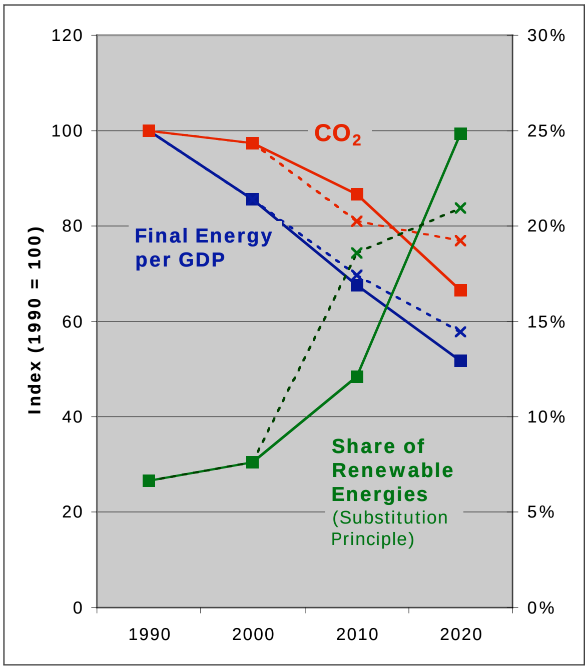
Source: Own calculations based on Mantzos *et al.* (2003)

The P&M scenario will lead to an emission reduction in the transport sector of around 396 Mt CO_2 (see Figure 24). In the P&M scenario, the increase in transport demand will be slightly curbed, and energy demand will cease to rise and begin to fall after 2010, such that CO_2 emissions can be reduced still further. By 2020, emissions will fall below 2000 levels first by technical efficiencies, followed by demand-side measures and increased use of biofuels. Major contributors to total CO_2 emissions in 2020 will be trucks (42%), passenger cars (36%) and aviation (15%). However, aviation has the highest growth rate of CO_2 emissions of all transport modes, rising by 2.2% per year between 2000 and 2020 (cf. trucks: +0.2% pa; passenger cars: -1.9% pa). Even if these policies and measures are implemented successfully by 2020, transport sector emissions will still be above 1990 levels. A stabilization at 1995 emission levels is possible under the P&M scenario. This will be an important step in the right direction given the enormous rise predicted in transport activity.

4.7 Exkurse: Comparison of the energy part of the P&M scenario with the recent EU scenarios on key drivers

Shortly after finalization of the main scenario calculations for this study the Directorate-General Energy and Transport (DG TREN) released a new report on "European energy and transport scenarios on key drivers " (Mantzos *et al.* 2004). This report refers to the baseline developed by Mantzos *et al.* (2003) and analyses a number of different scenarios and cases; e.g. the effects of higher energy prices, higher or lower GDP-growth, and of certain policies.

Figure 25: Comparison of the P&M scenario with the EU EPO case



Source: Mantzos et al. (2004) & own calculations; EPO-Case: dotted lines

One of these cases follows a more or less comparable philosophy with the policies and measures scenario developed here. In the "extended policy options" (EPO) case, high efficiency and a high renewables component are combined with an ambitious policy that addresses GHG emission reductions in the transport sector and the introduction of higher energy taxation and emissions trading for the EU25. However, the EPO case only assumes implementation of strong policies and measures up to and including 2010. After that time no new policies and measures are assumed and this leads to a somewhat unrealistic break in the development of energy efficiency and renewable energies[20].

The similarities and differences between the two scenarios – on the one hand the Wuppertal Institute policies and measures scenario and on the other the DG TREN extended policy options case, – are shown in Figure 25.

Energy efficiency plays a major role in both scenarios. Up to 2010 the P&M scenario assumes slightly higher efficiency gains, with smaller differences regarding sectoral efficiency developments. By 2020 the difference is shown to increase, due to the assumption in the EPO case that no further development of policies and measures will occur after 2020.

Increased use of renewable energies is the second main strategy in both scenarios. Here the EPO case assumes much faster increases up to 2010 than does the P&M scenario. After 2020 however, the P&M scenario purports a continuation of the support for renewable energies, unlike the the EPO case which then leads to much slower increases in market share for renewable energies up to 2020 (21% against 25% of gross energy consumption).

These trends are also mirrored in the resulting developments of CO_2 emissions in the EU25. Up to 2010, both scenarios more than achieve the Kyoto target for the EU25 as a whole. The EPO case reaches a reduction of almost 19% of CO_2 emissions against 1990 levels, while the P&M scenario reaches only 13%. After 2010 the picture changes, the EPO case arriving at a total emissions reduction of 23% by 2020, whereas the P&M scenario achieves a reduction of 33%.

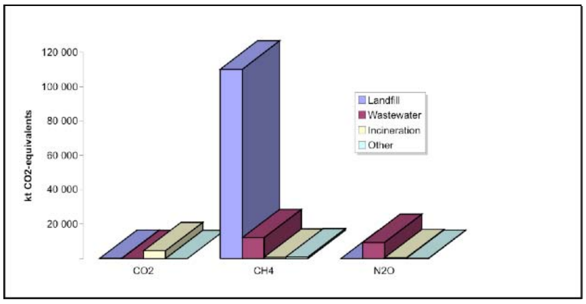
[20] This point is acknowledged by the authors in their paper.

4.8 Reduction of other greenhouse gases

4.8.1 Waste

In 2000, about 3% of total GHG emissions in the EU25 resulted from waste management, excluding the energetic use of waste that is counted under energy use (IPCC 1996). The emissions are mainly caused by methane (CH_4) from landfill sites (about 80%). Other sources, e.g. waste-water handling and waste incineration, do not account for a significant share of overall emission, as Figure 26 shows. CO_2 and N_2O gases play only a minor role.

Figure 26: Greenhose gas emissions from the waste sector in 2000, EU25



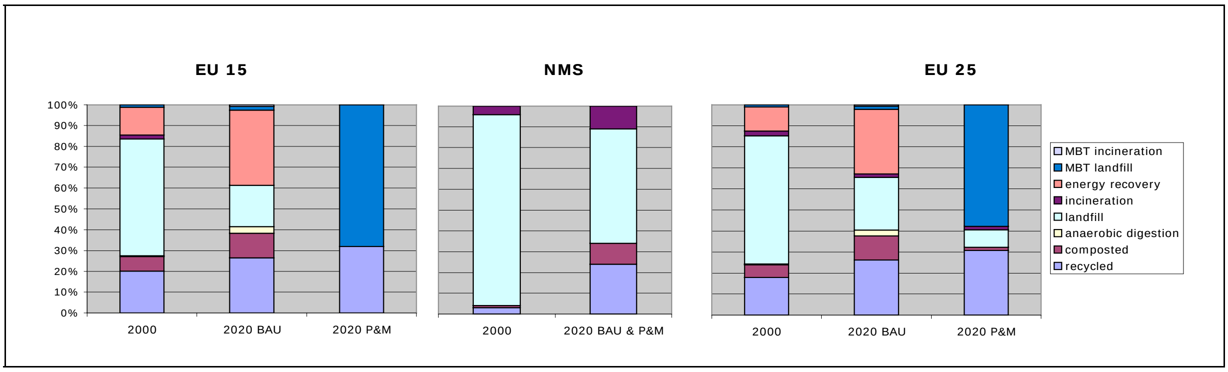
Source: UNFCCC (2005); own calculation

The development of future emissions from waste basically depends on two factors: the amount of waste produced and how will it be treated. Between 1998 and 2001, around 550 kg of municipal solid waste (MSW) were generated per capita per annum in Western Europe. In the new member states this figure amounted to 358 kg (Eurostat 2003). Landfill was the treatment most commonly used in both the EU15 (56%) and the NMS (89%). With faster-growing living standards the amount of waste per person is expected to increase both in the EU15 and the NMS, with higher growth rates in the latter.

GHG mitigation strategies currently focus on waste treatment. Reasonable options are enhanced recycling and mechanical biological treatment (MBT) of landfill waste, as assumed in the P&M scenario.

The EU Landfill Directive (LD), if properly implemented in member states, should lead to crucial GHG reductions. In addition, the Packaging Waste Directive provides for a certain amount of waste to be recycled or incinerated at a waste incineration plant with energy recovery. Waste incineration should only be an intermediate step, however. Better solutions are genuine recycling and the push for greater share of MBT.

Figure 27: Waste treatment in the EU15 and the NMS, 2000 and 2020

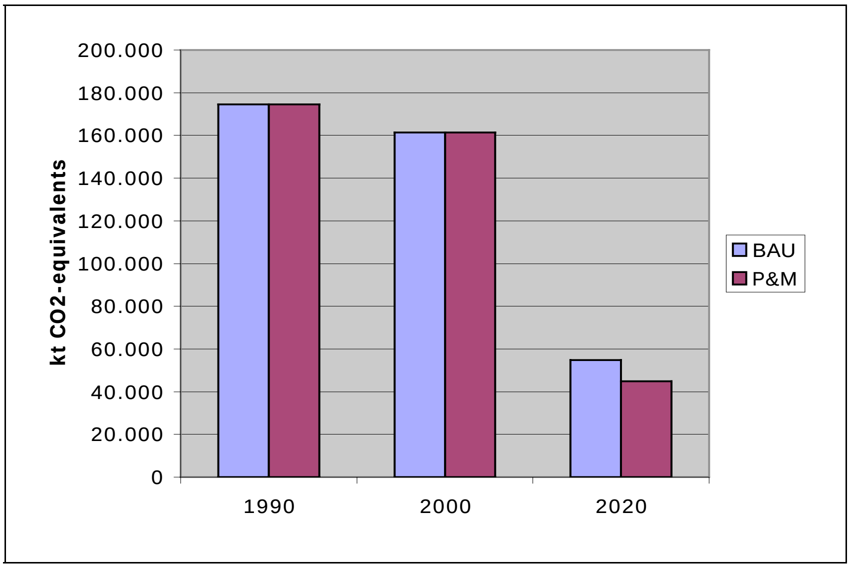


Source: AEA Technology 2001; IPTS 2003; own calculations

In the BAU scenario, it is assumed that the LD will be successfully implemented in the EU25, and national policies are taken into account. The LD restricts the amount of biodegradable waste dumped in landfill sites to 35% of 1995 levels by the year 2016 (or 2020 for states which dumped more than 80% of their waste in landfills in 1995). Moreover, the directive states that landfill gases should be collected and used for energy generation "where possible".

In the P&M scenario, waste treatment is restricted to recycling and MBT, with residues sent to landfills for the EU15 until 2020, whereas for the NMS 100% implementation of the Landfill Directive is assumed, as in the BAU scenario. This leads to the outcomes illustrated in Figure 5.

Figure 28: GHG emissions from the waste sector



Source: UNFCCC; own calculations based on IPTS; AEA Technology

If the Landfill Directive is fully implemented by member states, as assumed in the BAU scenario, this measure alone will reduce GHG emissions from waste management by more than two-thirds. In the P&M scenario, with increasing recycling quotas and greater MBT shares, a further emissions reduction of about 10 million tons of CO_2-equivalent by 2020 is possible. Figure 28 summarizes these outcomes.

4.8.2 Agriculture

GHG emissions from the agricultural sector were responsible for ca. 11% of total emissions in 2000 in the EU25 (UNFCCC 2005)[21]. Two gases are predominant: methane (CH_4) and nitrous oxide (N_2O).

The bulk of agricultural N_2O emissions (89% in 2000) comes from agricultural soils, arising from microbial processes of nitrification and denitrification. A small amount (10%) of nitrous emissions also results from manure management.

CH_4 emissions are mainly attributed to livestock farming, mainly of cattle, with enteric fermentation responsible for about 68%, and manure management responsible for about 31% of all agricultural CH_4 emissions in 2000. Methane emissions from rice cultivation only account for about 1% in the EU25 and are neglected in the following.

[21] Emissions from energy use in agriculture are – according to the IPCC guidelines (1996) – accounted for in the tertiary sector.

For both the BAU and the P&M scenarios the analysis is based on key indicators, representing the main sources of GHG emissions. These are the number of cattle for enteric fermentation and manure management, and the area of agricultural soils.

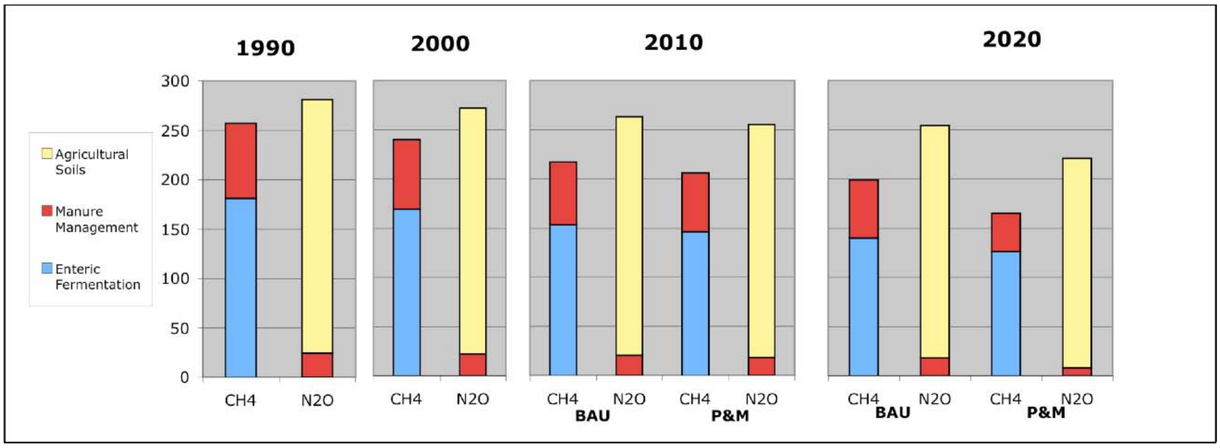
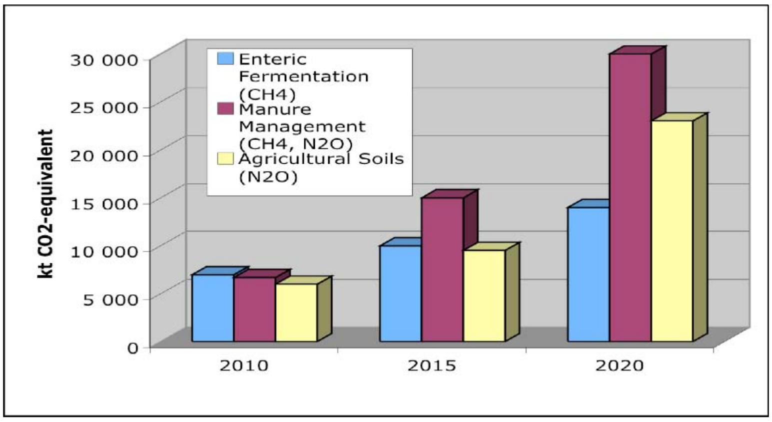


Figure 29: Agricultural greenhouse gas emissions, EU25 1990 to 2020

Source: UNFCCC (2005); own calculations based on FAO (2004) data

As Figure 29 shows there is already a clear downward trend for GHG emissions in the BAU scenario. In 2020 a reduction of emissions of more than 15% as against 1990 levels is likely due to a decline in agricultural production. Nevertheless, there is room for further emission reductions if corresponding measures are taken. In the P&M scenario emission reductions can be almost doubled vs. BAU. Compared to 1990 emissions can be reduced by about 28 %.

Figure 30: Emission reduction potentials in agricultur



Source: Freibauer 2002; MIDAIR (2004); own calculation

Mitigation measures (cf. Freibauer 2002) are: increased feed conversion efficiency through improved feed intake or the replacement of roughage by concentrates which reduce CH_4 emissions from enteric fermentation. Feed additives are also a possible option but should be considered with care as animal health could be affected. With regard to manure management, improvements in storage conditions can lead to significant reductions. The cooling of manure to reduce microbial activity, by optimizing climatic conditions and covering of manure, is another crucial component. A shift from aerobic to anaerobic digestion in combination with heat and power generation is an important solution that also fits into the strategy of renewable energy generation (see 4.2). For agricultural soils, increased fertilizer use efficiency through improved fertilization techniques, or a better match of nitrogen supply with crop demand, will lead to reductions of N_2O. Wetland restoration may reduce nitrate transport to surface waters and coastal areas (cf. Groffmann *et al.* 2000). Tightening nitrogen flows in farms (e.g. manure re-use in plant production) can also contribute to reductions.

It is important to note that the possible impacts of measures in agriculture hold some uncertainties. This is because biological, as opposed to physical, processes are the basis of the analysis. Thus the saving potentials assumed in the P&M scenario (see Figure 30) are estimated rather conservatively.

4.8.3 Emissions of HFCs, PFCs, SF_6

The applications of the so-called F-gases are numerous and varied, and differ from country to country. Usually they are categorized into the production and the consumption of the respective gases (cf. UNFCCC 2005):

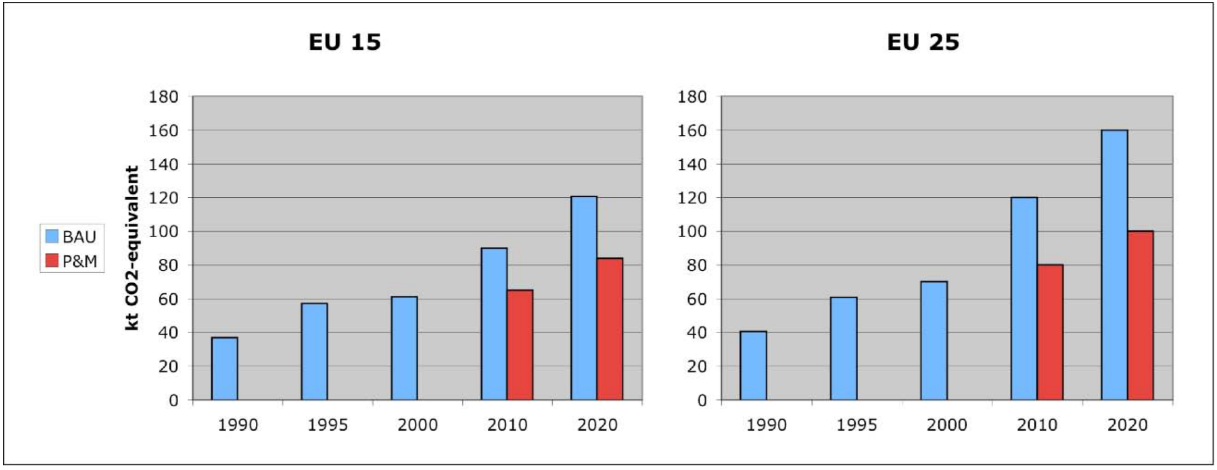
- The main applications for HFCs (hydrofluorocarbons) are stationary or mobile climate and cooling systems and use as an agent in the manufacture of insulation material and foams.
- Emissions of PFCs (perfluorocarbons) result primarily from processes in the semiconductor and aluminium industry.
- SF_6 (sulphur hexafluoride) is mainly applied in sound isolation, as a protective gas in magnesium production, as an isolating gas in electrical equipment, and as an acid gas in the semiconductor industry (UBA 2004).

In 2000, the F-gases were responsible for about 1.6% of total GHG emissions in CO_2 equivalents (UNFCCC 2005) in the EU15. Figures for the NMS are estimated to be relatively low at this time (cf. IIASA 2004).

F-gases have increasingly come into use since the ban on CFCs under the Montreal Protocol in 1987, as substitutes for CFCs mainly in climate and cooling systems. It is therefore expected that the consumption of Halocarbons and SF_6 will rapidly increase in a number of applications, overcompensating by far the decreasing uses in others. There is huge uncertainty in the figures, however, brought about by different structures in different countries, time schedules for the substitution of ozone-depleting substances, and the specificity in national data provision (cf. IIASA 2004). Even historical data differ between different studies. ECOFYS, for example, assumes higher figures for the EU15 in 1995 than IIASA does for the EU25 (ECOFYS *et al.* 2001; IIASA 2004).

This constraint should be borne in mind when viewing Figure 31 , which is based on average values for the period 1990 to 2020.

Figure 31: Emissions of HFCs, PFCs and SF6, 1990 to 2020



Source: UNFCCC (2005); ECOFYS et al. (2001); IIASA (2004); EEA; own calculations/estimates

To mitigate the fast-growing emissions of F-gases in the BAU case, action is needed within a wide range of applications and processes, particularly in cooling appliances). A key strategy is the substitution by other, less harmful substances or by technical substitution processes. At the same time, leakage reduction in cooling systems and extinguishing gas applications should be brought forward.

Similar measures are applicable in the semiconductor and magnesium industry, substituting F-gases with other substances and optimizing production processes. High reduction rates of PFC emissions can also be achieved in the aluminium industry by shutting down non-prebake anode smelters and increasing recycling (Mipiggs 2005).

A reduction in F-gases against the base year (1990) is not possible because in 1990 these gases did not play a major role in the applications in which they are used today. Given their widely increasing function as substitutes for CFCs and the range of processes and products they are now used in, over a longer time period (i.e. until 2040) a reversal of the trend and a clear reduction to below 1990 levels seems feasible, if appropriate policies are implemented.

5 A Comprehensive climate policy strategy for the EU

A targeted policy strategy both at the EU level and at member state level is necessary in order to change course in the EU energy sector and to realize the GHG emission reductions described in the P&M scenario.

Such a policy strategy has to combine tough and detailed targets for sectors and GHG with a consistent and comprehensive set of policies and measures of all types and in all sectors (cf., e.g., the set of targets and policies outlined in the recent Green Paper on Energy Efficiency [European Commission 2005b]).

Energy efficiency, notably energy end-use efficiency, plays a crucial part in minimizing GHG. It demands technical, organizational and behavioural improvements at all stages of the energy cycle – i.e. on the supply as well as on the demand side. Sometimes it is not possible to clearly differentiate between these categories, – i.e. demand and supply-side options often overlap or interact. For example, increased energy efficiency in households leads to less energy demand, which can ease the task for energy suppliers to achieve commitments under the EU emissions trading scheme (ETS). Nevertheless, action is necessary in all areas of the energy sector; the most important issues and the cross cutting policies and measures required are described in the following section (5.1).

Even under BAU conditions, general technical progress leads to more efficient products and processes. However, it is not sufficient to simply offset growing final energy consumption brought about by higher living standards and higher population and economic growth. In industry, for example, final energy demand is projected to grow by 16.9% for the period 2005-2020; this already takes into account a structural change to less energy-intensive manufacturing processes. For the residential sector the growth figure is 12.3%, incorporating changes in the fuel mix as well as technological improvements in buildings and equipment. Tertiary sector energy use is expected to grow by 19.1%, while energy demand for transport will increase by 22.9%.

These increases counteract the expected effects of fuel switching and reductions of other greenhouse gases in the BAU scenario. This means that the Kyoto target of a reduction of almost 8% (EU15: 8%; NMS: 7.8%) for CO_2, CH_4, N_2O, PFCs, HFCs, and SF_6 between 2008 and 2012 will be missed by about four percentage points.

From these figures it becomes clear that – in spite of huge potentials to reduce energy intensity – the general technical improvements assumed in the BAU case can only limit the growth rate of final and primary energy demand, without actually reducing it to any significant degree. Further policies and measures to accelerate technical improvements and to increase the market shares of best available technologies are necessary. Besides targeted policies and measures in every sector (see 5.2 below), a number of cross-cutting policies are crucial for implementing the potentials and achieving the targets. The most important are:

- strengthening of the EU emissions trading scheme in order for it to fully unfold its potential to achieve the GHG reduction targets. To achieve this, a regulatory ETS framework is required that guarantees: (i) sufficiently tight caps on emissions by EU member states; and (ii) a structural definition of the ETS across Europe which sets out the appropriate incentive structures for the required fuel switch, efficiency gains and technology developments, and the deployments required to reduce emissions.

Further, better interaction and support of the ETS by other policies should be ensured (see 5.1.1);

- o further steps towards an ecological finance reform at EU and member state level, with a priority on the removal of subsidies and the long-term promotion of higher energy and carbon pricing (see 5.1.2);
- o stringent and quick implementation of the EU directives already under way so as to complete a supportive framework for energy services and energy-efficiency programmes, thereby creating a functioning market structure for the potential multi-billion Euro market for energy-efficiency services and technologies (see 5.1.3);
- o legal and fiscal support for renewable energies (see 5.1.4) and combined heat and power production (see 5.1.5);
- o support for energy agencies (national and regional) and consumer organizations, as well as intensified marketing of energy efficiency, CHP and renewable energies.

5.1 Cross-cutting policies and measures

5.1.1 The EU emissions trading scheme

The European Union has created and introduced an emissions trading scheme (ETS) which has acquired a leading role as the overall guiding legislation for absolute CO_2 reductions.

The principles of the cap-and-trade regime established by the ETS effectively regulate the overall CO_2 emissions of all installations with a thermal power of more than 20 MW (i.e. most of the fuel use in industry and electricity generation). Further sectors and GHG may be added. EU member states define one state-wide emission ceiling for a certain trading period for these installations and distribute respective allowances to the operators; operators are then able to trade these allowances among each other in order to fulfil their obligations. However, this also means a ceiling on the remaining sectors which have to make up the difference between the ETS cap and the total Kyoto target of the respective state.

In 2000, the emissions falling under the regulation of the ETS (energy-related CO_2 emissions of industry and power generation) amounted – according to our modelling results – to about 2 billion tons of CO_2 or about 55% of energy-related CO_2 emissions of the EU25. In the BAU scenario, the emissions of the installations falling under the ETS slightly decrease by about 4% by 2010 and rise again by 2020 to a level about 4% higher than in 2000. The P&M scenario shows that in the power sector and in industry the biggest potentials for GHG emission reductions are achievable through higher energy efficiency (both in the supply and end uses) and increased use of renewable energy. Emissions could decrease by almost 19% by 2010 and by more than 900 million tons or 45% by 2020. This is equivalent to **an overall annual discounting of allowances on average of about 3.2% per year between 2005 and 2020**. In the P&M scenario, **more than 60% of the overall emission reductions achieved between 2000 and 2020 are thus connected to installations falling under the ETS**.

This highlights the strategic importance of the ETS for emission reductions. It is thus **most important that EU member states impose stringent caps** on their industries and power sectors which reflect the necessary decrease in total supply.

By setting tough caps and appropriate rules and structures, ETS participants are forced to look for abatement options and for progressive and less emission-intensive or even emission-free technologies. However, to increase political **feasibility** in setting the caps at the tough level required, **comprehensive sector- and technology-specific policy packages must be in place to support markets** for energy end-use efficiency (electricity in all sectors, and fuels for the industry sectors covered by the ETS), renewable energy sources for electricity production, and CHP. This will make it easier for ETS participants to reach, and hence, to accept tough caps. For all other sectors not covered by the ETS, structural and specific policy measures are also relevant and necessary.

In combination with the ETS, additional specific policies and measures must serve two key objectives:

1. A reduction of GHG emissions that are not covered by the ETS (including non-CO_2 greenhouse gases these are more than 55% of the total GHG emissions). For this a comprehensive and ambitious policy package is needed, with a particular focus on demand-side energy efficiency for heat and transport, renewable energies for heat generation and transport, and combined heat and power production.
2. Support for demand-side energy efficiency, electricity end-use and supply efficiency, and in particular for renewable energies in the sectors covered by the ETS. These aspects are not sufficiently assured – at least in the short run – by the effects of the ETS, and it is unlikely that the ETS alone will harness the full potential of energy end-use efficiency measures. Renewable energies demand a higher initial investment and, given the current industry situation, also need a supportive political framework. In addition, the incentives offered by the ETS need to be strengthened and deployed more frequently.. Sector- and technology-specific policies and measures are needed to reduce transaction costs for energy efficiency and renewable energies, and to accelerate market introduction and technology learning. Accompanying policies and measures that provide mitigation options, as well as helping to overcome counteracting barriers and/or short-term higher costs are therefore necessary.

Reducing electricity consumption by 20% above BAU levels by 2020, and a doubling of the use of renewable energies and of CHP through technology-specific policies will enable EU member states to set tough CO_2 emission caps for the electricity generation industry, as well as the energy-intensive industries covered by the ETS.

To conclude, the necessity for EU member states to follow a strictly decreasing pathway for their emission caps and to structure future ETS frameworks in a manner that provides sufficient incentives for energy efficiency, a switch in fuel, and for new technology developments cannot be overestimated. Further, it is essential that the ETS be combined with stringent energy-efficiency and renewable energy policies for those sectors outside the ETS regime and for the ETS sectors to accelerate technology development and deployment.

5.1.2 Energy taxes and ecological finance reform

Ecological finance reform aims at harmonizing fiscal regulations and ecological targets. This means in general that higher fiscal loads have to be imposed on the use of finite resources, and be removed from human resources and capital in order to improve their performance.

As a consequence, tax exemptions, subsidies and other support for the use of fossil and nuclear (uranium) resources – e.g. exemptions on aviation fuels, asymmetric taxation of fuels for electricity generation[22] and fuels for transport (e.g. between diesel and gasoline) (cf. Schlegelmilch 2004) – have to be reduced.

The taxation of energy and/or GHG emissions can play an important role in creating supportive framework conditions for climate protection strategies. Energy-efficiency investments become more attractive and renewable energies can be promoted by setting tax rates according to respective emission levels. The revenues from these taxes can be used, *inter alia*, to promote energy efficiency and renewable energy forms through targeted subsidies. Within the framework of ecological tax reform, such revenues are used mainly to reduce labour costs and improve employment situations.

This concept has been implemented successfully in several EU member states, leading to significant energy savings, e.g. the ecological tax reform in Germany, the climate change levy in the UK, the taxation of electricity and natural gas for households in The Netherlands, and the taxation of final energy and of car registration in Denmark (cf. Jørgensen 2003).

At the EU level, energy taxation has been discussed for more than a decade. After a 1992 European Commission proposal for a CO_2/energy tax proved unsuccessful, it was not until 2003 that a more modest proposal, to introduce and gradually increase environmental taxation on energy products, was eventually agreed. It entered into force at the beginning of 2004 and has now to be transposed into national legislation among the member states. While this is taking place, it cannot be said that it is being implemented in an environmentally ambitious way; for instance, it is now legally feasible to tax kerosene for aviation and to abolish the tax differential between diesel and gasoline for private use. To be truly effective, energy taxation, as a potentially powerful instrument for stimulating long-term energy efficiency and renewable energies, needs to be implemented at the level of member states or groups of member states[23].

5.1.3 EU-level policies for energy efficiency

Restructuring and liberalizing the supply side of electricity and gas markets only addresses half of the market for least-cost energy services. The other half is **demand-side energy efficiency**, and this has not yet received enough support from EU and national policies.

The recently published Green Paper Green Paper on Energy Efficiency promotes an effective energy-efficiency policy as a “major contribution to EU competitiveness and employment” (European Commission 2005b). The Green Paper states that about 20% of current energy consumption in the EU could be saved by cost-efficient measures. This is already a substantial share of the final energy savings of 22% compared with BAU – or 27% of present EU energy demand – discussed in the P&M scenario and also deemed cost-effective.

At the EU level, the following policy initiatives should be adopted as soon as possible and/or stringently implemented:

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[22] E.g. in Germany natural gas used in power plants and in heating systems is taxed much higher than coal in spite of its lower GHG emissions (see Lechtenböhmer, Irrek & Kristof 2004).

[23] See e.g. www.eco-tax.info

- The proposed **Directive on energy end-use efficiency and energy services**. This directive should set a mandatory target for achieving additional energy savings in end-use sectors not covered by the ETS. As the P&M scenario includes average energy savings in the residential, commercial and transport sectors of 1.7% per year compared with BAU, or 23% by 2020, a target should be set, with success measured and verified by simple but sufficient bottom-up methods. The directive will require member states to stimulate energy-efficiency services and to create a financing framework for energy-efficiency programmes, for example through energy-efficiency funds (based on, e.g., Danish and British examples: see www.elsparefonden.dk and www.est.co.uk, and also Thomas & Irrek 2005) or via energy-savings targets set for energy companies, as already introduced in the UK, Denmark, Italy, and Flanders (Belgium) (OFGEM 2004). Such supportive policy has proven most effective, especially where a combination of an agreed or mandated, quantified target for energy savings, a channel or an allowance for raising funds, and a standardized and mandatory scheme for cost-benefit evaluation of the energy-efficiency activities has been created. Indeed, in those member states which have combined the implementation of the EU Internal Markets for electricity and gas with a supportive policy framework, **energy-efficiency programmes** are continuing or even expanding in volume and scope. In member states lacking such an approach, these activities have gradually reduced. If the best practice examples in energy-efficiency programmes and services that exist in some EU countries were extended to the whole EU and continuously developed, they alone could **reduce EU electricity, gas and heating oil consumption by at least 15% compared to BAU within the next 15 years** (cf. Wuppertal Institute et al. 2002, 2003);
- Implementation of the recently agreed directive on eco-design requirements for energy-using products, combined with targets for new appliances set at levels close to the technical optimum;
- A revised framework directive on energy labelling, including more types of energy-using products;
- National implementation and further revisions of the directive on the overall energy performance of buildings towards inclusion of all buildings in order to achieve the highest possible emission cuts.

5.1.4 Best practice policy mix for the promotion of renewable energies

At the EU level, active implementation of the RES-Electricity Directive and the biomass action plan and development of a new RES-heat directive are needed in order to realize the targets under the directive and to prolong this trend until 2020. Furthermore, support should be provided to member states in implementing appropriate policies and measures.

The most successful national level policies and measures have to be applied in the EU RES policy mix to meet the ambitious RES targets in the P&M scenario. These include:

- fixed feed-in tariffs that have already boosted wind power growth in, e.g., Denmark, Germany[24] and Spain;
- support for installation of solar collectors, e.g. soft loans and direct investment grants as e.g. in Germany, or by making RES mandatory in building codes as in Spain;
- market entry of biofuels, e.g. driven by tax exemptions.

Besides financial support, there exists a range of mandatory non-economic measures for successful RES development in Europe:

- Grid access and power purchase agreements in combination with feed-in tariffs;
- Accelerated building permission procedures for RES plants (especially wind power plants);
- Comprehensive training on RES technologies and their application for installation contractors, retail sales staff, architects and engineers.

In the P&M scenario an EU-wide RES policy mix is assumed that consists of the most successful national level policies and measures in order to reach the ambitious RES targets. The European RES policy mix is determined by the combination of the above-mentioned economic and non-economic policies and measures to support the market entry of RES in the different sectors.

5.1.5 Policy for the support of combined heat and power generation

Because of its potential for energy and emission savings, enhancement of the framework conditions for CHP is one of the principal components of policies for GHG reductions:

- In the short term there is the need to consolidate the operation of existing cogeneration plants. This could be guaranteed by bonus systems or feed-in tariffs. Power plants operating at low efficiency should receive similar special incentives for early replacement. Additionally, a quantitative target for power produced by CHP can be a sufficient measure (cogeneration quota).
- Another big potential lies in the construction of new CHP plants within existing heating networks that are not yet providing electricity. Again, this could be supported by financial incentives as well as CHP quotas etc.
- Subsidies for the construction of district heating networks, linking industrial cogeneration facilities with neighbouring heat consumers, can promote public/private partnerships.
- For small-scale applications, it is essential to achieve a critical market volume that would allow for significant cost reduction and technological optimization. Grants and low-interest loans might provide a way forward. Nevertheless, the technology, especially micro-turbines, Sterling engines and fuel cells, requires demonstration and learning programmes. Moreover, an information and support scheme would be helpful for optimizing energy performance, perhaps on a partnership basis between an investor/operator of CHP plants and industrial, commercial and/or public

[24] Recent studies in Germany have shown that feed-in tariffs are more cost effective for the promotion of wind energy than other regulations (BWE 2005).

consumers. A feed-in tariff for the electricity generated by highly efficient small-scale CHP could be used to boost this market, analogous with the success of renewable energies.

- o Finally, it is important to establish a well-functioning market for reserve and back-up power for independent or self-supplying operators of CHP plants, to provide these services at competitive prices, for times when the plant is not in operation or when demand exceeds self-production.
- o Instruments that serve to foster the development of small and very small CHP schemes are (i) clear regulations of the technical and market conditions for the purchasing of CHP electricity by national grid companies, and (ii) guaranteed fixed feed-in tariffs for electricity from small CHP plants.

The promotion of combined heat and power generation needs an active and integrated strategy defined within a renewed and effective EU directive for the support of CHP in industry, district heating and micro-CHP. This will harmonize rules across Europe and align supportive instruments with the ETS. Such a strategy should comprise:

- a supportive framework for investment in industrial and municipal CHP plants. Maintenance and development of district heating grids etc. has to be supported, and attractive conditions created for the use of heat from power plants;
- clear support, such as less restrictive planning regulations, for small CHP plants in small, decentralized district heating systems, e.g. in new residential, commercial or industrial developments;
- a scheme for an accelerated development, technological improvement and market introduction of micro-CHP units. This could be achieved, for example, by inclusion of CHP-friendly rules in building codes, soft loans and other subsidy schemes, in cooperation with market partners such as gas distribution companies.

5.2 Sectoral policies and measures

In this section, key sectoral policies and measures are listed. Many are also mentioned in the Green Paper on Energy Efficiency by the European Commission (2005b). Serious implementation of existing legislation is key to achieving substantial improvements in energy efficiency over and above the BAU trend. The Commission considers in its Green Paper that half of the overall energy-efficiency target set for the EU to attain by 2020 can already be reached through effective use of existing legislation (European Commission 2005b, 37). However, a comprehensive package of the cross-cutting policies and measures discussed above and active implementation of the sectoral strategies indicated below is necessary in order to achieve all of the GHG reduction potentials identified, and to realize the energy and emission pathway described in the P&M scenario (which goes beyond the target of 20% energy savings proposed in the Green Paper, see 5.1.3 above).

5.2.1 Policies and measures for the power sector

The power sector, which in 2000 produced roughly one-third of the total CO_2 emissions in the EU, is crucial to any successful climate protection strategy. This should focus on the four functional levels of the sector: heat and power production, transmission grids, distribution networks, and supply, since important potentials and drivers for emission reductions exist in each.

Heat and power production

Four key strategies are assumed for the supply side:

- Increased penetration of renewable energy sources (see above);
- Increased use of combined heat and power production (see above);
- Fuel switch to low carbon fuels;
- Efficiency improvement in the supply side.

The core policy instrument to achieve significant emission reductions in the power sector is the EU emissions trading scheme. For small-scale installations in particular it should be combined with:

- a clear strategy towards support of efficient CHP, particularly small-scale CHP, by adequate instruments such as fixed tariffs for electricity, feed-in regulations for micro-CHP, quotas or subsidy schemes, and clear regulations on the technical and market conditions for the purchasing of CHP electricity by the grid companies (see 5.1.5);
- clear support for increasing market share of renewable energies, in particular in electricity and district heat generation. Here, feed-in tariffs based on, for example, the German experience with technology-specific fixed and decreasing tariffs for renewable electricity generation, combined with active support to develop sites and exploit potentials, are the instruments of choice (see 5.1.4).

Furthermore, EU member states should ensure that, where tendering for new capacity is carried out according to article 7(1) of the internal market directive, least-cost resources are chosen. This gives actors developing demand-side resources a fair chance to take part in the tender.

Transmission and distribution network sectors

The following strategies are important for electricity and gas transmission and distribution system operators:

- In price regulation, better align the evolution of revenues and profits with the evolution of cost drivers, thereby removing the incentives to operators to increase wheeling (the amount of electricity transported through their grids). In addition, remove disincentives to energy-efficiency activities by
  - recovery of direct costs of an energy-efficiency programme within tariffs;
  - recovery of net lost revenues owing to reduced sales from energy efficiency within tariffs;
  - additional energy-efficiency incentives within tariffs or prices.
- Introduce energy-efficiency obligations on distribution system operators, as, for example, in Italy, Denmark, or Flanders (Belgium);

- Ensure effective implementation of the internal market directive (Article 14(7)) which obliges distribution system operators to carry out least-cost planning, including demand-side resources;
- Support implementation of demand-side measures as a least-cost option and alternative to replacements, upgrades or extensions of the grid;
- Improve framework conditions for the participation of load reduction measures in the tenders of transmission system operators for reserve capacities available within short time periods (one minute);
- Reduce grid losses;
- Promote energy-efficient transformers (which have the potential to save more than 20 TWh/a in the EU).

Energy supply companies

Energy suppliers should be obliged and motivated to include, in their marketing and billing, information on the impacts of customers' energy consumption on climate change, and on reduction measures that can be carried out by the customer.

In addition, suppliers should be obliged to carry out energy-efficiency activities (such as in the UK's Energy Efficiency Commitment). Incentives should be provided to help them develop from pure end-use energy suppliers to energy service companies offering energy-efficient solutions to the customer, and bringing value-added benefits such as involvement in energy-efficiency rebate systems (as practised in the Netherlands until October 2003).

5.2.2 Policies and measures for the residential sector

To achieve significant improvements in energy efficiency in the residential sector a policy mix is necessary, including policies aimed directly at the performance of **electric appliances**, such as:

- extension of energy labelling to all appliances (especially consumer electronics and home office equipment), and with a revision of labelling every three years to guarantee that only the most efficient appliances are A-rated;
- minimum energy-efficiency standards, especially for standby appliances.
- These measures should be accompanied by financial support mechanisms, such as:
  - rebate schemes for A- or A+/A++ -rated appliances, as well as compact fluorescent lamps (CFL) and/or dedicated fixtures for CFLs. to accelerate market penetration of the most efficient appliances. This means that buyers should get a discount on prices for energy-efficient appliances. Such a scheme was run successfully in The Netherlands until 2003, helping A-rated appliances to become dominant in the market and making the market share of the most efficient A+ and A++ appliances the highest in the EU (see: www.energiepremie.nl).
  - funds for research and public or cooperative procurement projects in new technology, helping to develop high-efficiency appliances and solutions for energy-efficiency services.

- o increased incentives for architects and planners to design energy efficient buildings.

In addition, greater information and knowledge among all involved parties will help to heighten sensitivity towards energy efficiency. Supporting policies should cover:

- o intensifying local/regional consumer advice;
- o education and training of traders and installers;
- o support for cooperative procurement schemes.

Finally, cross-cutting policies like energy-efficiency funds, or binding targets for energy suppliers (e.g. the Energy Efficiency Commitment in the UK), or distribution network operators can lead to crucial reductions in energy demand.

In the field of **residential space and water heating**, including the renovation and insulation sector, a policy mix is necessary to exploit the huge savings potential. An important first step is effective implementation of the EU Directive on the energy performance of buildings, which should be extended to cover all existing buildings. Policies to be implemented or intensified are:

- o an increase in heating system efficiency (standards/labelling, effective national implementation of Article 8 of the EU Directive on the energy performance of buildings);
- o introduction of an effective European standard for single building components (e.g. k-values for windows);
- o introduction of regular energy audits for larger buildings;
- o obligatory installation of solar water heating for new and renovated buildings, e.g. by regulation in planning and construction laws.

Direct support for less energy intensive and environmental friendly measures is one crucial means of achieving improvements. Particular options are:

- o rebate schemes for thermal insulation, A-rated boilers, heating controls, and energy-efficient circulation pumps;
- o introduction of financial support schemes for the construction of low-energy, zero-energy and passive[25] houses, to include solar-powered water and heat generation that will add to energy savings;
- o feed-in tariffs for biomass (see renewables) and small-scale CHP.

Additional financial support should be provided by:

- o increased incentives for architects and planners;
- o funds for research projects in new technology;
- o funds for increased measurement and verification of refurbishments.

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[25] Passive houses are highly insulated buildings which do not need 'active' heating systems (see www.passivhaus-institut.de).

To increase the information/knowledge base for practitioners and decision-makers in the building and construction industry, the following policies are suggested:

- Education and training of traders and installers as they are in direct contact with end-users and can influence consumer decisions;
- Intensification of local/regional consumer advice.

5.2.3 Policies and measures for the tertiary and commercial sector

Three main policies are assumed to be useful to mitigate rapidly rising energy demand in the tertiary and commercial sector.

First and most importantly, financial and technical assistance is needed for the owners of *existing* commercial buildings to harness the enormous potentials for energy savings both in the installed equipment and the building fabric. This includes high-quality, low-cost energy audits, and financial support for investments. Support for the demand and supply of energy performance contracting and similar energy-efficiency services is also needed. Funding for these measures could come from energy-efficiency funds or from energy companies that have an obligation to provide funds, coupled with an allowance for cost recovery in the network tariffs (see 5.2.1).

Secondly, stringent national implementation and the further extension of the EU Buildings Directive is necessary. The directive itself should set stricter standards for energy consumption and be extended to smaller buildings. Other necessary steps are regulations making improvements to existing buildings mandatory, and stringent implementation of regulations governing installed equipment (lighting, ventilation, air conditioning etc.) Together with the mandatory labelling of buildings, active information campaigns are needed to increase the awareness for the energy consumption and the number of low-energy buildings in the real estate market. Within this framework, end-use and sector-specific energy and electricity consumption targets, e.g. per square metre, should be made mandatory. As a first step in this direction, voluntary agreements with sectors on these targets could be reached (e.g. office buildings that meet certain standards of consumption for their heating, air conditioning and lighting, the energy demand of the installed equipment, or comparable standards for retail buildings).

Furthermore, energy-efficient design of commercial buildings and their installed equipment is also important. Professional training of architects, engineers and installation technicians should include methods for integrated energy-efficient building design and corresponding installation skills.

Thirdly, labelling and minimum standards for the increasing number of electric appliances are highly desirable. Under the Eco-Design Directive for Energy-Using Products, strong and dynamically improved minimum standards for office equipment and installed appliances such as air conditioning or pumps should be implemented. Independently monitored voluntary agreements with producers and public sector procurements are additional measures to help to further push the best available technology on the market.. The public sector should take the lead in this field and adopt stringent rules for procurements, e.g. leasing equipment and buildings only with best available technology.

5.2.4 Policies and measures for industrial energy use

The most important policy to achieve the acceleration of energy efficiency in fuel use (e.g. by harnessing cost-effective saving potentials in industry) is the further development of the EU emissions trading scheme. Adequate caps have to be set and specific provisions have to be introduced in order to better align the other policies and measures with the ETS (see 5.1.1).

However, additional instruments are necessary, especially for achieving the huge electricity savings potentials and for the implementation of industrial CHP. These include:

- instruments to improve energy efficiency in industry through energy audits, particularly supporting the link between energy audits and subsequent implementation measures; energy management; energy services; energy-efficiency programmes; and targeted motivation, information (including benchmarking of the energy consumption of typical industrial processes) and R&D;
- use of the IPPC-directive to improve best available technology (BAT) for various industry processes and to increase pressure for the implementation of BAT in industry;
- financial incentives for the installation and optimization of specific energy-efficient cross-cutting technologies (e.g. pumps, HVAC systems, ventilators, lighting sensors);
- minimum standards for energy-consuming products – in industry mainly for motors and drives. These standards should be developed and implemented through continuous improvement of the Eco-design Directive;
- promote the combining of load management and energy-saving measures with improved framework conditions for including load reduction measures in reserve capacity management by transmission operators. The bundling of load reduction potentials will enable large industry or energy-service companies (ESCOs) to participate in the respective tenders by transmission system operators for rapid delivery of reserve capacities.
- legal and technical definitions and standards plus further additional measures to ease the implementation of energy performance contracting in industry by ESCOs and other market actors;
- Affordable and soft loans for energy-efficiency investments.

5.2.5 Transport policy mix

To reduce GHG emissions in the European transport sector, a policy mix is necessary which comprises ambitious fuel-efficiency improvements and the creation of standards, reductions in road and air transport activity (by optimization of logistics and modal shifts), and increasing the consumer base for biofuels. The key policies and measures to accomplish emission reduction targets in the transport sector are:

- increasing fuel efficiency for all modes of transport – especially air and road transport – by including vehicles in the Eco-design Directive and the planned Energy End-use Efficiency Directive;

- enhanced agreement between the European Commission and automobile manufacturing associations (ACEA/JAMA/KAMA), with obligatory measures and timetables. The average specific emission target for the passenger car fleet should be reduced to 100 g CO_2 per vehicle kilometre by 2020. In addition, such agreements could be extended to cover trucks and aircraft with the relevant manufacturers;
- a modal shift from individual car and freight transport to public transport systems and rail freight transport, as well as increased pedestrianism and cycling;
- improved traffic management systems and optimization of freight transport logistics;
- achieving a biofuel share of 14.3% in 2020 of all fuels sold for road transport;
- an emissions trading scheme in the aviation sector combined with improved air traffic management systems and the phasing out of subsidies/tax exemptions and the introduction of, for example, excise duties on fuels, value-added tax (VAT) for international travel, route charges and/or kerosene tax (Pastowski 2003);
- increasing tax levels for the least energy-efficient cars and reducing tax levels for the most energy-efficient cars.

5.2.6 Policies to reduce greenhouse gas emissions in non-combustion sectors

Apart from CO_2 emissions from fuel combustion, which forms the bulk of all European Union GHG emissions, other emissions and non-combustion sectors are relevant to and should be included in a climate protection strategy. Important among them are the fugitive emissions (mainly methane emissions from coal mines and the oil and gas industry) from energy use in the waste, agriculture and industry sectors. Although substantial reductions have already been achieved or will be achieved by existing policies and measures, there are still reduction potentials that could be targeted by sector-specific policies and measures. These include:

Policies for GHG reductions in the waste sector

- Compliance with the Landfill Directive should be strictly enforced in all EU member states;
- Recycling quotas in the Packaging Directive can be increased;
- Waste taxes, based on the level of environmental impact, are an effective means of reducing harmful materials;
- A quota for mechanical and biological treatment of waste will also help to reduce GHG emissions.

Policies for non-energetic GHG reduction in agriculture

- For the reduction of emissions from enteric fermentation the feed conversion efficiency could be brought forward by fixing food composition, i.e. by introducing quotas for additives or concentrates;
- Manure management can be improved by free advice/audits on the farms and investment incentives for heat and power production from biogas. Feed-in tariffs for power from biogas are another promising instrument (see also section 4.2 on renewable energies);

- With regard to GHG emissions from agricultural soils, fertilizers can be improved by according standards, and wetland restoration can be encouraged by paying premiums per hectare of restoration.

Policies for emission reduction of fluorinated gases

- The legislation currently on the way for regulation of certain fluorinated gases and the directive relating to emissions from air conditioning systems in motor vehicles should quickly pass through the European Parliament and the European Council.
- Further policies on substituting fluorinated gases in new equipment where technically feasible (in production and consumption), and optimization guidelines for technical processes seem reasonable.

6 Risk minimization by P&M

As a result of the active climate policy in the P&M scenario – which basically consists of an energy-efficiency strategy in demand sectors and heat and power plants, promotion of CHP, and support for an accelerated introduction of renewable energies into the market –the development of the European energy market takes a different direction than expected under BAU conditions.

The strategies proposed in the P&M scenario will, in turn, reduce a number of risks notably those imposed by:

- the changing climate;
- increasing import dependency on limited ressources; and
- the vulnerability of energy systems to the above risks and to technological issues.

Climate Change

Climate change – e.g. increasing temperatures, changes in precipitation patterns and greater incidence of natural disasters – is a scientifically accepted result of increasing GHG emissions. The varying effects of climate change on all sectors of human activity are a notable threat to human lives and economic activity and well-being, as well as ecosystems, as exemplified by:

- A WHO quantitative assessment, taking into account only a subset of the possible health impacts, concluded that “the effects of the climate change that has occurred since the mid-1970s may have caused over 150,000 deaths in 2000. It also concluded that these impacts are likely to increase in the future” (WHO 2005);
- Low precipitation can result in a lack of cooling water for power plants and a restriction of inland navigation due to low-water levels in rivers. It can also put farming activities at risk in certain areas, e.g. in the leeward regions of mountains;
- Heavy storms and torrential rains that lead to flooding can cause substantial damage on infrastructure and inhabited land;
- High summer temperatures lead to rising energy demands for air conditioning, resulting in increasing power generation and resource consumption;
- Financial impacts from, for example, damage to infrastructure and losses in revenue, are and will be felt across a wide range of sectors, not only those directly emitting CO_2 or other GHG.

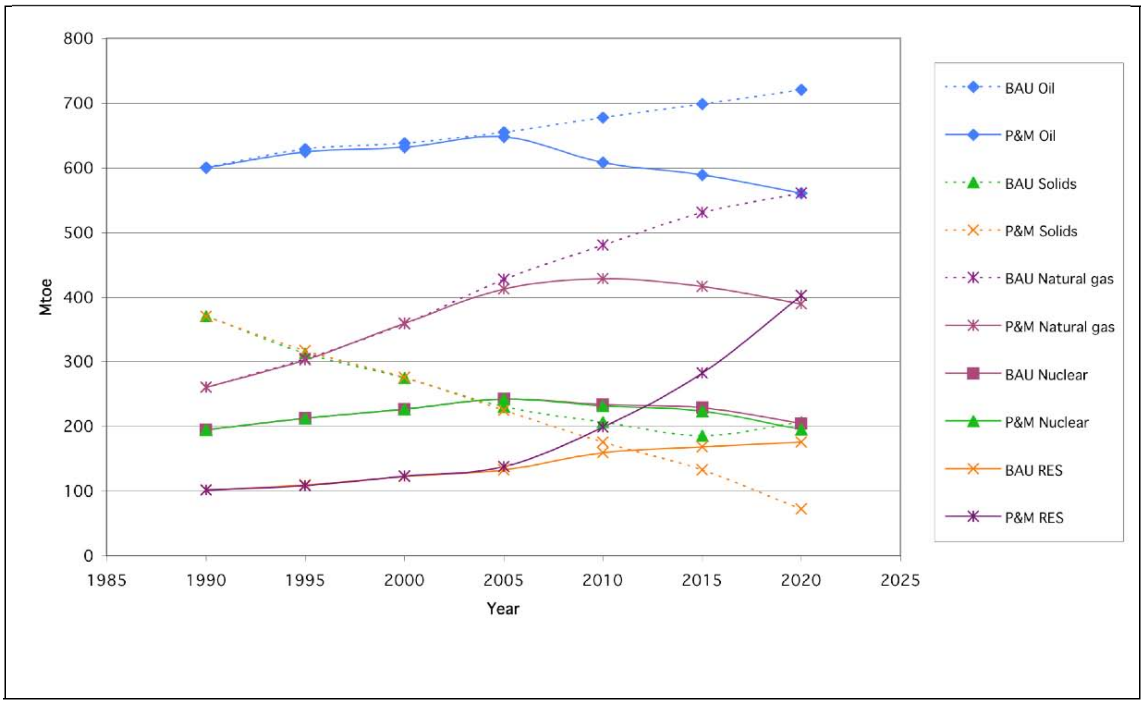
The economic effects of natural disasters, power outages or damage to transport infrastructure brought about by climate change have to be recognized. A recent report by the European Environment Agency makes it clear that impacts of climate change are already being observed in the EU (EEA/ACC 2004). The EU has therefore agreed on targets to limit GHG emissions (European Commission 2005), but the success of current policies and measures is limited and GHG emissions targets will not be reached in the BAU scenario. The P&M scenario, however, assumes decreasing GHG emissions which reduce the direct and indirect risks associated with climate change and the attendant risks to the energy and transport infrastructure in Europe.

Import dependency

The climate strategy will work from two sides to stabilize import dependency at more or less current levels:

1. With increased energy efficiency on the demand side, final energy demand slightly decreases by 0.4 % per year. In the transformation sector an almost similar trend will be established. In total, gross domestic energy demand will decline slightly below current levels, contrary to the BAU trend.
2. The climate protection strategy achieves an increasing EU energy production by about 0.5% per year after 2005. The increased production of renewable energy will offset reductions in conventional fuel production. As a result, imports of coal will fall away to almost nothing and oil imports will decrease at 0.5% per year. Gas imports – due to the fuel switch towards gas – will continue to grow but with significantly decreased rates compared to the past and to the BAU projections.

Figure 32: Gross domestic energy consumption in the EU 25, BAU and P&M scenario



Source: own calculations, for BAU, based on Mantzos *et al.* (2003)

These two effects – reducing energy consumption through energy efficiency at all levels and maintaining domestic production by increased production of renewable energies – not only makes climate mitigation possible, but also makes it possible at the same time to not further increase import dependency. Domestic energy production will be able to deliver about half of the European energy consumption.

This reduces a wide range of risks and problems associated with the current unsustainable trend of import dependency:

- Costs of imported energy for the European economy can be curbed by between US$60 and US$120 billion by 2020 (0.3 to 0.6% of GDP) compared to the BAU scenario, depending on price scenario and the Euro/US$ exchange rate;
- Price risks and risks of supply shortages are reduced;
- The pace of exploitation of important energy resources is slowed down globally, thus reducing the potential for international conflicts and the danger of exploding energy prices;
- Moreover, the EU establishes itself as a leader in moving towards a more sustainable world energy system. By stabilizing its own oil demand on world markets, supply shortages and subsequent price shocks are reduced (peaking of oil production is expected by most experts to occur before 2020). If others follow the EU lead, the balancing of oil production capacity and the demand for oil will be much easier than under BAU trends.
- The European Commission estimates in its Green Paper on Energy Efficiency that saving 20% of energy by 2020 could generate up to 1 million jobs in the EU (European Commission 2005b).

By adopting the P&M scenario as opposed to BAU it will be possible to:

- minimize economic risk – and at the same time minimize ecological risk;
- reduce as far as possible the risks and potential costs of climate change;
- reduce other environmental damage – expressed as external costs of energy supply.

Technological issues regarding energy and transport infrastructure

The climate system and the energy system are deeply interlinked. Therefore the discussion about the risks the energy system is exposed to has to incorporate the vulnerability and resilience of both the climate and the energy system. Climate change is mainly caused by energy -related GHG emissions. Climate change means temperature and precipitation changes, rising sea levels and increased incidence of natural disasters, all of which affect the energy and transport system in Europe, with consequent rebound effects on interdependent systems.

Technological issues contribute to the vulnerability and exposure of the European energy sector in several ways (Luhmann 2004). The electricity infrastructure in particular incorporates the following risks:

- The proportion of high-risk technologies such as nuclear energy increases in the BAU scenario. Conversely, the P&M scenario includes a nuclear moratorium and therefore a decreasing nuclear risk;
- Power plants and the electricity grid have a long lifetime and therefore require long-term investment. This brings a lack of flexibility in adapting to changing requirements (e.g. environment, demand, resources prices) as well as financial exposure. A high share of decentralized CHP and RES electricity generation in the P&M scenario limits this risk considerably;

- Furthermore, the general risks of centralized energy systems where technological failures and cascading effects are concerned decreases in the P&M scenario as a result of decentralized generation with CHP and RES plants;
- The technical and financial feasibility of future technologies is unknown to a large extent and only predicted in scientific analysis. Sound research, development and testing of prototypes over years deliver the feasibility of new concepts. The R&D process itself contains risks, but focusing the whole R&D on single technologies bears even greater risks of economic feasibility and the time horizon of market entry. For example, the strong support of carbon capture and sequestration technologies as the future key CO_2 emission reduction technology seems risky, because of a variety of uncertainties, no proven storage concept and no running prototype plant until now. A similar risk arises out of the time horizon for the development of hydrogen generation, storage and use technologies. The P&M scenario highlights GHG emission reductions without focusing on future technologies. To a wide extent, emission reductions are gained with energy-efficiency measures and RES with practical proven technologies;
- In addition, material constraints for the market introduction of new technologies (e.g. fuel cells) might be a risk in the future (c.f. Krewitt et al 2004).

In the BAU scenario the vulnerability and exposure of the European energy and transport infrastructure is higher than in the P&M scenario. The resilience is strengthened in the P&M scenario by renewable and decentralized electricity generation technologies, a decreasing import dependency, and energy-efficiency measures.

7 Conclusion

From the scenario analyses carried out in this study – which is based on a number of scenario studies for a range of sectors and supplemented by the Wuppertal Institute's own analysis and assumptions – it can be concluded that an integrated and active climate protection strategy for the EU is ambitious but feasible. However, to achieve it, the EU economy must speed up improvements in energy efficiency and adapt power generation systems to renewable energy supplies. In addition, it must minimize risks of disruptions to energy supply and of increasing energy prices, as well as risks associated with global warming.

- The analyses presented show that by pursuing an active strategy of policies and measures, there are huge and cost-effective potentials for improved energy efficiency in all sectors, stabilization of EU energy consumption below current levels, and that renewable energy sources can contribute 25% of overall energy production by 2020.
- In addition, an overall 33% reduction of CO_2 emissions from fuel consumption is possible by 2020, compared with 1990 levels, even with a moratorium on nuclear energy. Further GHG reductions, chiefly in the agricultural sector (e.g. by increased use of biogas) and the waste sector, are possible.
- The results also show that a 30% reduction in European Union GHG emissions by 2020, as envisaged by the European Parliament on 13 January 2005, is achievable by adopting the strategies outlined.
- Another important finding is that an active climate protection strategy can yield further benefits in the form of massively reduced risks of energy shortages and energy price peaks, as well as improved resilience of the European energy system. It releases the European economy from high energy costs, creates a net increase in employment – the European Commission Green Paper on Energy Efficiency estimates that an energy saving of 20% by 2020 could generate up to 1 million jobs in the EU – and also reduces other environmental burdens.

In order to move away from business-as-usual trends that lead to increased energy demand, greater dependency on foreign resources, and put the attainment of a sustainable energy system increasingly at risk, a comprehensive policy package is needed. The European emissions trading scheme forms a key part of such a package as it covers sectors responsible for almost 60% of the total emission reductions expected by 2020. For the ETS to achieve its full potential, strict and reliable long-term emission reduction paths are crucial, with EU member states responsible for achieving national caps on emissions. This has to be accompanied by a comprehensive set of sector- and technology-specific policies and measures for energy end-use and supply efficiency, CHP, and electricity generation from renewable energies. Targeted and intensive policies and measures for transport energy efficiency, support for thermal uses of renewable energies, and support for CHP heating and renovation of households are also essential.

The results of this analysis demonstrate that the strategy described by the policies and measures scenario outstrips the “muddling through” approach of business-as-usual. Given the current slippage in meeting GHG reduction targets and the increasing evidence of quickening climate change, EU policy-makers are well advised to further enhance the substance, longevity and reliability of the ETS, intensify and accelerate efforts to speed up GHG mitigation and energy-efficiency improvements in all sectors, support further expansion of CHP, and to prioritize renewable energy sources within the necessary reinvestment of a large proportion of the European power plant stock.

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Annex I – Tables

Table 2: GHG emissions of the EU 25 in the BAU scenario, by sector and gases

Sector/Gas in Gg CO_2-eqivalent	1990	2000	2010	2020	2020/ 1990
1A Fuel combustion	3,836,243	3,749,143	3,834,702	4.110.957	7%
1B Fugitive emissions from energy	153,653	101,571	95,623	90.579	-41%
2+3 Industrial processes	327,468	282,473	347,966	381.445	16%
4 Agriculture	538,084	512,782	481,372	453.751	-16%
6 Waste	174,499	139,128	103,382	54.782	-69%
Total (without removals)	5.029.947	4,785,098	4,863,044	5,091,514	1%
CO_2	3,960,425	3,862,614	3,952,718	4.220.376	7%
CH_4	562,204	457,968	394,559	322.904	-43%
N_2O	466,317	403,716	395,766	388.234	-17%
HFCs, PFCs, SF_6	41,000	60,800	120,000	160.000	290%
Other greenhouse impacts from stratospheric aircraft transport	*116,693*	*168,215*	*253,627*	*403.069*	*245%*
Total including other impacts from aircrafts	*5.146.640*	*4,953,313*	*5,116,672*	*5,494,584*	*7%*

Source: own calculations

Table 3: Comparison of BAU and P&M Scenario

				BAU scenario			P&M scenario			
	1990	**2000**	**% pa '90-'00**	**2020**	**% pa '00-'20**	**% delta to 1990**	**2020**	**% pa '00-'20**	**% delta to BAU 2020**	**% delta to 1990**
GDP (in 10^9 Euro'00)	7.32	8.94	2.03%	14.46	2.43%	97.7%	14.46	2.43%	0.0%	97.7%
Final Energy Demand (Gtoe)[26]	1.00	1.06	0.51%	1.32	1.12%	31.5%	1.03	-0.14%	-22.3%	2.2%
Gross Inl. Consumption[27]	1.55	1.64	0.58%	1.90	0.71%	22.2%	1.65	0.01%	-13.2%	6.1%
Renewable Energies (Gtoe)	0.10	0.12	1.91%	0.18	1.81%	72.9%	0.40	6.11%	128.9%	295.7%
Renewables share	6.6%	7.5%	1.32%	9.3%	1.08%	41.4%	24.5%	6.10%	163.6%	272.9%
CO_2 Emissions (Gt CO_2)	3.76	3.67	-0.23%	4.02	0.46%	7.0%	2.52	-1.87%	-37.4%	-33.0%
Import Dependency	50.2%	54.3%	0.78%	67.6%	1.10%	34.6%	52.2%	-0.20%	-22.8%	3.9%
Energy Intensity Indicators (1990 = 100)										
Industry (Energy / Value added)	100	83	-1.9%	60	-1.6%	-39.6%	48	- 2.7%	- 20.0%	- 51.7%
Residential (Ener./priv. income)	100	88	-1.3%	66	-1.4%	-33.9%	52	- 2.6%	- 21.4%	- 48.0%
Tertiary (Energy / Value added)	100	84	-1.7%	63	-1.4%	-37.0	48	- 2.7%	- 23.3%	- 51.6%
Transport (Energy / GDP)	100	98	-0.2%	82	-0.9%	-17.5	62	- 2.1%	- 24.3%	- 37.6%
Method of accounting for primary energy from renewable electricity generation: EC: Eurostat Convention SA: Substitution Approach										

Source: own calculations, for BAU: based on Mantzos *et al.* (2003)

26 1 Gtoe is equivalent to 41.869 PJ.

27 Gross inland consumption equals primary energy demand.

Table 4: GHG emissions of the EU 25 in the P&M scenario, by sector and gases

Sector/Gas	in Gg CO_2-eqivalent	1990	2000	2010	2020	2020/ 1990
1A	Fuel combustion	3,836,243	3,749,143	3 352 211	2 574 713	-33%
1B	Fugitive emissions from energy	153,653	101,571	92 192	70 291	-54%
2+3	Industrial processes	327,468	282,473	304 549	311 361	-5%
4	Agriculture	538,084	512,782	461 672	386 751	-28%
6	Waste	174,499	139,128	99 382	44 970	-74%
Total (without removals)		5.029.947	4,785,098	4 310 006	3 388 086	-33%
	CO_2	3,960,425	3,862,614	3 477 885	2 706 691	-32%
	CH_4	562,204	457,968	373 634	252 916	-55%
	N_2O	466,317	403,716	378 488	328 480	-30%
	HFCs, PFCs, SF_6	41,000	60,800	80 000	100 000	144%
	Other greenhouse impacts from stratospheric aircraft transport	*116,693*	*168,215*	227 990	286 256	145%
Total including other impacts from aircrafts		*5.146.640*	*4,953,313*	4 537 996	3 674 342	-29%

Source: own calculations

Table 5: CO_2 Emission and indicators of the power sector BAU EU25

BAU EU25	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
% of electricity from CHP	13,8%	14,6%	14,1%	13,7%	14,0%	15,0%
% of electricity from RES	12%	13,5%	14%	16,3%	16,6%	16,6%
Efficiency of thermal power plants	36%	37%	39%	43%	46%	47%
CO_2 Emissions in Mt of CO_2	**1336**	**1277**	**1191**	**1185**	**1183**	**1306**

Source: own calculations; Mantzos *et al*. (2003)

Table 6: CO_2 Emission and indicators of the power sector P&M EU25

P&M EU25	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
% of electricity from CHP	13,8%	14,6%	14,1%	17,9%	21,3%	23,5%
% of electricity from RES	12%	13,5%	14%	19,7%	27,2%	38,4%
Efficiency of thermal power plants	36%	37%	39%	43%	47%	49%
CO_2 Emissions in Mt of CO_2	1336	1277	1191	1078	915	656

Source: own calculations

Table 7: Primary Production of RES in the BAU and P&M scenario

Mtoe	1990	2000	2010	2020	% share in 2020	% change pa '00-'20
	BAU					
Total	102	123	158	172		1.69 %
Hydro	69,0	73	69	68.1	39.6 %	-0.35 %
Wind	0.00	4.8	30.9	39.8	23.1 %	11.1 %
Biomass	31.9	43.9	55.1	59.8	34.7 %	1.61 %
Other	0.48	1.64	3.02	4.26	3.6 %	4.89 %
	P&M					
Total	102	123	199	402		6.10 %
Hydro	69,0	73	71.2	82.0	20.4 %	0.62 %
Wind	0.00	4.8	26.6	71.3	17.7 %	13.5 %
Biomass	31.9	43.9	86.9	200	49.8 %	7.9 %
Other	0.48	1.64	14.1	48.8	12.1 %	20.24 %

Source: Own calculations based on European Commission (2004b); BAU based on Mantzos *et al.* (2003)

Table 8: RES Electricity Generation in the P&M scenario, EU 25

GWh/a	2005	2010	2015	2020	Share 2020	% change pa
Biomass	36500	112000	227000	407500	32 %	17.5%
Geothermal Electricity	6000	8000	11000	15000	1.2 %	6.3%
Hydro Large > 10 MW	326891	341834	365777	395520	31 %	1.3%
Hydro Small< 10 MW	13000	13600	13600	13600	1.1%	7.9%
PV	1309	5821	14334	29847	2.3%	23.2%
Solar Thermal Electricity	1000	5000	12000	24120	1.9%	23.6%
Tide & Wave	0	10428	18695	31963	2.5%	11.9%
Wind Onshore	55000	102000	152000	203000	15.9%	9.1%
Wind Offshore	0	30800	81400	152698	12.0%	17.4%
Total	439700	629484	895807	1273247	100%	11.5%

Source: Own Calculations based on European Commission (2004b)

Table 9: RES Heat Generation in the P&M scenario, EU 25

Ktoe	2005	2010	2015	2020	Share 2020	% change pa
Biomass	40.000	52.000	67.500	83.617	59.0%	7.7%
Geothermal	776	1.100	1.850	2.772	2.0%	13.6%
Heat Pumps	3.845	10.786	17.827	25.140	17.7%	20.7%
Thermal Collectors	2.250	9.200	17.800	30.230	21.3%	29.7%
Total	46.872	73.086	104.977	141.759		11.7 %

Source: Own calculations based on European Commission (2004b)

Table 10: Biomass input in electricity production 2020, P&M scenario, EU25

	Electricity production (GWh)	% Share
Solid Biomass	267 410	65.5 %
Biogas	104 236	25.5 %
Biowaste	36 495	8.9 %
Total	408 141	

Source: Own calculations based on European Commission (2004b)

Table 11: Electricity consumption for wet/cold appliances and lighting in GWh (EU 25)

	1990	2000	2020
Wet Appliances			
a) washing machines			
BAU	43,742	40,629	43,303
P&M	43,723	40,629	36,086
b) dishwasher			
BAU	17,247	20,732	25,014
P&M	17,247	20,732	20,845
c) tumble-drier			
BAU	15,733	26,185	38,697
P&M	15,733	26,185	26,535
Cold Appliances			
a) freezers			
BAU	48,696	43,964	42,234
P&M	48,696	43,964	29,176
b) refrigerator (incl. Fridge-freezer)			
BAU	92,480	87,831	80,422
P&M	92,480	87,831	55,946
Lighting			
BAU	93,821	104,171	113,256
P&M	93,821	104,171	71,324

Source: own calculations based on CECED 2001, ECI *et al.* 1998, ECI *et al.* 2000.

Table 12: Energy demand in tertiary and commercial sector by fuels

ktoe	Development 1990	2000	%/year vs. 1990	BAU 2020 2020 ktoe	%/year vs. 2000	P&M 2020 2020 ktoe	%/year vs. 2000	% vs. BAU
solid fuels	14.400	3.033	-14,4%	628	-7,6%	480	-8,8%	-23,6%
hard coal	*4.666*	*1.501*	*-10,7%*	*506*	*-5,3%*	*386*	*-6,6%*	*-23,6%*
coke	*1.372*	*664*	*-7,0%*	*85*	*-9,8%*	*65*	*-11,0%*	*-23,6%*
other solids	*8.363*	*869*	*-20,3%*	*37*	*-14,6%*	*28*	*-15,7%*	*-23,6%*
liquid fuels	47.172	39.452	-1,8%	36.929	-0,3%	27.377	-1,8%	-25,9%
diesel oil	*39.768*	*34.654*	*-1,4%*	*32.972*	*-0,2%*	*24.354*	*-1,7%*	*-26,1%*
residual fuel oil	*4.706*	*2.022*	*-8,1%*	*924*	*-3,8%*	*706*	*-5,1%*	*-23,6%*
other petroleum products	*2.698*	*2.776*	*0,3%*	*3.034*	*0,4%*	*2.317*	*-0,9%*	*-23,6%*
gaseous fuels	28.649	44.418	4,5%	55.434	1,1%	36.027	-1,0%	-35,0%
natural gas	*27.822*	*44.360*	*4,8%*	*55.434*	*1,1%*	*36.027*	*-1,0%*	*-35,0%*
derived gases	*827*	*58*	*-23,3%*	*0*	*-100,0%*	*0*	*-100,0%*	-
biomass	1.528	2.440	4,8%	2.778	0,7%	3.450	1,7%	24,2%
Other renewables	187	228	2,0%	379	2,6%	3.617	14,8%	854,3%
steam	9.534	8.640	-1,0%	11.237	1,3%	7.307	-0,8%	-35,0%
electricity	43.347	56.044	2,6%	86.465	2,2%	70.508	1,2%	-18,5%
Total	**144.817**	**154.255**	**0,6%**	**193.850**	**1,1%**	**148.765**	**-0,2%**	**-23,3%**

Source: own calculations; BAU from Mantzos *et al.* 2003

Table 13: Energy demand in industry by fuels

ktoe	Development 1990	2000	%/year vs. 1990	BAU 2020 2020 ktoe	%/year vs. 2000	P&M 2020 2020 ktoe	%/year vs. 2000	% vs. BAU
solid fuels	70.482	44.290	-4,5%	31.580	-1,7%	18.048	-4,4%	-42,9%
hard coal	*26.421*	*19.322*	*-3,1%*	*13.459*	*-1,8%*	*8.145*	*-4,2%*	*-39,5%*
coke	*32.411*	*21.785*	*-3,9%*	*17.089*	*-1,2%*	*9.418*	*-4,1%*	*-44,9%*
other solids	*11.650*	*3.183*	*-12,2%*	*1.032*	*-5,5%*	*485*	*-9,0%*	*-53,0%*
liquid fuels	50.191	40.284	-2,2%	35.486	-0,6%	26.064	-2,2%	-26,6%
diesel oil	*12.395*	*10.873*	*-1,3%*	*14.776*	*1,5%*	*10.853*	*0,0%*	*-26,6%*
residual fuel oil	*24.963*	*14.279*	*-5,4%*	*8.221*	*-2,7%*	*6.038*	*-4,2%*	*-26,6%*
other petroleum products	*12.833*	*15.132*	*1,7%*	*12.489*	*-1,0%*	*9.173*	*-2,5%*	*-26,6%*
gaseous fuels	82.448	92.624	1,2%	117.379	1,2%	64.211	-1,8%	-45,3%
natural gas	*67.782*	*83.018*	*2,0%*	*107.978*	*1,3%*	*57.307*	*-1,8%*	*-46,9%*
derived gases	*14.666*	*9.606*	*-4,1%*	*9.401*	*-0,1%*	*6.905*	*-1,6%*	*-26,6%*
biomass	4.031	4.610	1,4%	7.005	2,1%	8.699	3,2%	24,2%
waste	6.032	7.480	2,2%	9.248	1,1%	9.971	1,4%	7,8%
steam from cogeneration	34.093	29.471	-1,4%	43.615	2,0%	56.581	3,3%	29,7%
electricity	78.137	88.528	1,3%	120.518	1,6%	108.131	1,0%	-10,3%
Total	**325.414**	**307.287**	**-0,6%**	**364.831**	**0,9%**	**291.704**	**-0,3%**	**-20,0%**

Source: own calculations; BAU from Mantzos *et al.* (2003)

Table 14: Main indicators of BAU and P&M Transport Scenario

	1990	2000	'90-'00	2010	2020	'00-'10	'10-'20	2010	2020	'00-'10	'10-'20
				Bau		% change pa		P&M		% change pa	
Passenger transport activity (Gpkm)	4721	5671	1.8%	6766	8192	1.8%	1.9%	6789	8029	1.8%	1.7%
Freight transport activity (Gtkm)	1765	2149	2.0%	2691	3340	2.3%	2.2%	2652	3168	2.1%	1.8%
Final Energy Demand (Mtoe)	263	314	1.8%	375	428	1.8%	1.3%	330	324	0.7%	-0.2%
CO_2 Emissions (Mt CO_2)	785	942	1.8%	1107	1251	1.6%	1.2%	938	854	-0.1%	-0.9%
Energy intensity (toe/ MEuro '00)											
Passenger transport	23.4	22.2	-0.5%	19.6	17.1	-1.2%	-1.4%	17.3	12.3	-2.5%	-3.4%
Freight transport	12.5	13.0	0.4%	13.2	12.5	0.2%	-0.5%	11.5	10.1	-1.2%	-1.3%

Source: Own Calculations; BAU based on Mantzos *et al.* (2003)

Table 15: Share of CO_2 emissions reductions in transport sector by measure

	% annual change '05-'20		P&M Scenario	
	BAU	**P&M**	**Mt CO_2 reduction in 2020**	**Share of total emission reduction**
Demand Measures				
Passenger Road Transport	+ 1.4 %	+ 1.25 %	17	4.3 %
Aviation	+ 5.3 %	+ 4.0 %	34	8.6 %
Optimization of Logistics				
Road Freight Transport	+2.6 %	+ 1.7%	55	13.9 %
Efficiency Improvements				
Passenger Car	+ 1.1 %	+ 2.5 %	106	26.8 %
Aviation	+ 0.58 %	+ 1.55%	21	5.3 %
Trucks	+ 0.3 %	+ 1.0%	48	12.1 %
	Share in 2020			
Biofuels	3.6 %	14.3 %	115	29 %
Total			**396**	**100%**

Source: own calculations, for BAU: based on Mantzos *et al.* (2003)

Table 16: Comparison of WI P&M Scenario and DG TREN EPO case

	1990	2000	2010		2020	
			WI/WWF P&M	DG Tren EPO	WI/WWF P&M	DG Tren EPO
Gross Inl.Cons./GDP (toe/MEuro'00) **)	208.9	180.9	143.7	141.3	112.0	111.8
Final Energy Cons./GDP (toe/MEuro'00)	137.1	117.3	92.7	95.5	70.9	79.2
Share of Renewables in Gross Inl. Cons **)	7%	8%	12%	19%	25%	21%
Gross Inl.Cons./Capita (toe/inhabitant)	3.5	3.6	3.6	3.5	3.5	3.5
Electricity Generated/Capita (kWh/inhabitant)	5 584.9	6 344.3	6 895.8	8 059.6	7 142.8	7 523.5
CO_2 Emissions Index (1990=100)	100.0	97.4	86.7	81.1	66.5	76.9
Carbon intensity (t of CO_2/toe of GIC)	2.474	2.277	1.995	1.897	1.552	1.800
CO_2 Emissions/Capita (t of CO_2/inhabitant)	8.571	8.122	7.108	6.646	5.444	6.295
CO_2 Emissions to GDP (t of CO_2/MEuro'00)	516.9	411.9	286.7	268.1	173.9	201.1
Import Dependency*) %	51.0%	54.9%	56.0%	60.0%	53.0%	66.4%
Energy intensity indicators (1990=100)						
Industry (Energy on Value added)	100.0	82.6	63.1	68.5	48.3	57.0
Residential (Energy on Private Income)	100.0	87.6	67.0	70.5	52.0	56.9
Tertiary (Energy on Value added)	100.0	84.1	68.9	66.0	48.4	56.2
Transport (Energy on GDP)	100.0	95.9	80.4	74.7	62.4	61.9

*) own calculation, differing from Mantzos et al. (2004) nuclear energy is calculated as 81 % imported energy, due to the sources of uranium.

**) Renewable energies calculated according to Eurostat Convention

Source: own calculations for EPO case: based on Mantzos *et al.* (2004)

Table 17: Waste Treatment in 2000 in kt

	EU 15		NMS		EU 25	
Treatment	**Total**	**%**	**Total**	**%**	**Total**	**%**
recycled	37,497	20	930	3	38,427	17,8
composted	12,988	7	310	1	13,298	6,2
anaerobic digestion	716	0			716	0
landfill	103,663	56	27,590	89	131,253	60,9
incineration	3,687	2	1,240	4	4,927	2,3
energy recovery	24,788	14			24,788	11,5
MBT landfill	2,200	1			2,200	1
MBT incineration						
Total	**185,539**	**100**	**30,070**	**97**	**215,609**	**100**

Source: AEA Technology 2001; IPTS 2003

Table 18: Waste Treatment in 2020 in kt, BAU case

	EU 15		NMS		EU 25	
Treatment	**Total**	**%**	**Total**	**%**	**Total**	**%**
recycled	54,566	27	8,640	24	63,206	26,2
composted	24,139	11	3,600	10	27,739	11,5
anaerobic digestion	6,583	3			6,583	3
landfill	40,505	20	19,800	55	60,305	25
incineration			3,960	11	3,960	1,6
energy recovery	74,315	36			74,315	30,8
MBT landfill	3,627	2			3,627	1,5
MBT incineration	1,553	1			1,553	0,7
Total	**205,289**	**100**	**36,000**	**100**	**241,288**	**100**

Source: AEA Technology 2001; IPTS 2003

Table 19: Waste Treatment in 2020 in kt, P&M (GHG minimisation)

	EU 15		NMS		EU 25	
Treatment	**Total**	**%**	**Total**	**%**	**Total**	**%**
recycled	65,727	32	8,640	24	74,367	31
composted			3,600	10	3,600	1,5
anaerobic digestion						
landfill			19,800	55	19,800	8,1
incineration			3,960	11	3,960	1,6
energy recovery						
MBT landfill	139,562	68			139,562	57,8
MBT incineration						
Total	**205,289**	**100**	**36,000**	**100**	**241,289**	**100**

Source: own calculations based on AEA Technology 2001; IPTS 2003

Table 20: Emission Scenarios Agriculture EU 25 (in Mt CO_2-eq.)

	1990			2000			2010			2020		
	CH_4	N_2O	Tot.	CH_4	N_2O	Tot.	CH_4	N_2O	Tot.	CH_4	N_2O	Tot.
BAU												
Enteric Ferm.	181		181	169		169	153		153	140		140
Manure Manag.	76	24	100	71	22	93	64	20	84	59	18	77
Agr. Soils		257	257		250	250		243	243		236	236
Total	257	281	**538**	240	272	**512**	217	263	**480**	199	254	**453**
P&M												
Enteric Ferm.	181		181	169		169	146		146	126		126
Manure Manag.	76	24	100	71	22	93	60	18	78	39	8	47
Agr. Soils		257	257		250	250		237	237		213	213
Total	257	281	**538**	240	272	**512**	206	255	**461**	165	221	**386**

Source: UNFCCC (2005), own calculation based on FAO data (FAO 2004)

Table 21: Potentials in Agriculture in the EU 25 (in kt CO_2-eq.)

Potential Savings	2010	2015	2020
Enteric fermentation	7,000	10,000	14,000
Manure management	6,700	15,000	30,000
Agricultural Soils	6,000	9,500	23,000

Source: Freibauer (2002), MIDAIR Project (2004), own calculation

Table 22: Scenarios for HFCs, PFCs and SF_6

Kt CO_2-eq.	1990	1995	2000	2010	2020
			EU 15		
BAU	32,7-41	50,1-64,1	52,3 - 70	80-100	108,9 - 132
P&M	32,7-41	50,1-64,1	52,3 - 70	60-70	76 - 92
			EU 25		
BAU	36 - 45	51,6 - 70	60-80	110-130	140-180
P&M	36 - 45	51,6 - 70	60-80	70-90	90-110

Source: UNFCC (2005), ECOFYS et al. (2001), IIASA (2004), EEA (2004), own calculation/estimation

Annex 2 – Overview over Methods and Assumptions

Sector **Subsector / Appliance**	**Model / Split**	**Cost efficient emission reduction potentials** **Key Assumptions**	**References**	**Remarks (temporal & geographical coverage of reference)**	**Strategies / Core policies** **Key Assumptions**	**References**
Renewable Energies						
Electricity, heat, biofuels	EU-25 country specific data	80% of mid term potential used in 2020 with technology specific corrections (eg wind)	European Commission (2004b) EREC (2005) Nitsch (2004) Harmelink (2003) Bauen (2004): WWF BioPowerswitch!	mid term potentials technology specific	market push with best practise national RES policies: feed-in tariff, soft loans, investment grants, tax exemp-tions, grid access and power purchase agreement, accele-rated building per-missions, education	
Households						
Electricity consumption	Saving potentials vs. BAU for EU 15 and NMS	by main electrical appliances	Own analyses, CECED (2001) data. Bertoldi/Waide (1999) as comparison	Underlying detailed studies for EU 15 only; detailed calculation of savings potentials vs. BAU by partly adapting EU 15 data to NMS where reasonable	Assuming today`s best available technolgy as average technology in 2020	See under potentials
Fuel consumption	Saving potentials vs. BAU for EU 15 and NMS by fuel (including steam and renewable energies)	by fuel appliance	BRE *et al* (2002) Ecofys 2004	Underlying detailed studies for EU 15 only; extrapolation of savings potentials and fuel switch between coal, oil and gas vs. BAU for EU 25	Increased insulation in buildings, improved heating system efficiency, shift to gas and renewables	See under potentials
Direct use of renewable energy sources	For space and water heating in the EU 15 and NMS	Direct biomass use slightly increased vs. BAU Solar thermal and others significantly increasing	ECEEE (2004) further assumptions and sources see under renewable energies	Iterative pro-cess applied in order to pro-vide consistent developments and to avoid double coun-ting No explicit check for cost efficiency	Exploitation of solar potentials,	See under renewable energies / biomass
Steam use from CHP	Households as a whole for EU 15 and NMS	Increased use of steam from CHP, but lower growth as in BAU	For further assumptions and sources see under power sector	Iterative process applied in order to provide consistent developments and to avoid double counting	See under CHP	See under power sector / CHP

Tertiary & Industry						
Electricity consumption	Saving potentials vs. BAU for EU 15 and NMS	by electrical appliance and major industrial electricity consuming processes e.g. electric steel production, chlorine production	Own analyses, Fischedick et al (2002), Cremer et al. (2001) etc.	Underlying detailled studies for Germany only; extrapolation of savings potentials vs. BAU; assumption: saving potentials vs. BAU are comparable or bigger than in Germany	Exploitation of cost efficienty saving potentials	See under potentials
Fuel consumption	Saving potentials vs. BAU for EU 15 and NMS by fuel (including steam and renewable energies)	by fuel appliance and major industrial processes e.g. oxygen steel production, cement production	See under electricity	Underlying detailed studies for Germany only; extrapolation of savings potentials and fuel switch between coal, oil and gas vs. BAU; assumption: saving potentials vs. BAU are comparable or bigger than in Germany	Exploitation of cost efficienty saving potentials	See under potentials
Direct use of renewable energy sources	Industry as a whole for EU 15 and NMS	Direct biomass use slightly increased vs. BAU Solar thermal an others not explicitly covered	Assumptions and sources see under renewable energies	I Iterative process applied in order to provide consistent developments and to avoid double counting No explicit check for cost efficiency	Exploitation of biomass potentials, use of biomass in industrial boilers where technically feasible	See under renewable energies / biomass
Steam use from CHP	Industry as a whole for EU 15 and NMS	Increased use of steam from CHP as a substitute for natural gas	For further assumptions and sources see under power sector	Iterative process applied in order to provide consistent developments and to avoid double counting	See under CHP; maintaining of existing CHP and about 50 % of all new big industrial steam generators as CHP units	See under power sector / CHP

Transport						
Passenger Road transport	EU-15/NMS (demand side measures, fuel efficiency measures and biofuels implemented	100 g CO_2/vkm fleet average for new cars reached in 2020 modal shift	Based on Mantzos (2003) Sources for technology: Kageson (2005) Bates (2001) Ricardo (2003) sources for modals shift and demand reduction: CANTIQUE (2000) SCENES (2001), SCENES (2002) TREMOVE (2005)	hybrid cars, direct injection gasoline cars, shift to diesel, lightweight structures, friction and drag improvements, engine improvement, energy management, drive train improvements, biofuels	Including vehicle in Eco-design directive and energy end-use directive; Enhanced ACEA/JAMA/KAMA; modal shift supporting policies, tax level depends on efficiency of vehicle, tax exemption for biofuels	
Road freight transport	EU-25/NMS demand side measures, fuel efficiency measures and biofuels implemented	Increase of road freight activity slowed down Moderate energy efficiency improvements, modal shift?	Based on Mantzos (2003) Bates (2001) CANTIQUE (2000) SCENES (2001), SCENES (2002) TREMOVE (2005)	Optimising freight organisational measures, transport logistic, road telematic, driver training, intermodal freight transport. Engine and weight, improvements, aerodynamic drag and rolling resistance reduction, biofuels	Traffic management systems, freight transport logistic optimisation, tax exemption for biofuels	
Aviation	EU-25/NMS demand side measures and fuel efficiency measures implemented	fuel efficiency improvements; logistic optimisation	Source for technology: Lee (2003) demand development based on Airbus (2003) Source for demand reduction: SCENES (2001), SCENES (2002) TREMOVE (2005)	Airframe weight improvements, extended flight control systems, full hybrid laminar flow control, geared fan engine, alternative fuels	Including Aviation in emission trading scheme, improved air traffic mangement system, phasing out of subsidies and tax exemptions	Pastowski (2003) Wit (2005)

Annex 3 – Abbreviations and Units

Abbreviations

ACEA/JAMA/KAMA	European, Japanese and Korean automobile manufacturers associations
BAT	Best Available Technology
BAU	Business as Usual Scenario
CCGT	Combined-Cycle Gas Turbine
CDM	Clean Development Mechanism
CECED	European Committee of Domestic Equipment Manufacturers
CFL	compact fluorescent lamps
CH_4	Methane
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CO_2eq	CO_2 equivalent emissions (1 t CH_4 = 21 t CO_2eq; 1 t N_2O = 310 t CO_2eq.)
COP	Conference of the Parties
COP/MOP	Conference of the Parties serving as the meeting of the Kyoto Protocol
DG TREN	Directorate-General Energy and Transport
EC	European Commission
ECEEE	European Council for an Energy-Efficient Economy
EEA	European Environment Agency
EEA	European Environment Agency
EP	European Parliament
ESCO	Energy Service Company
ETS	[European Union] Emissions Trading Scheme
EU15	The 15 Member States of the European Union since the Year 1995
EU25	The 25 Member States of the European Union since the Year 2004
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross Domestic Product
GHG	Greenhouse Gas
H_2O	Water
HFC	Hydrofluorocarbons
HVAC	Heating, Venting, Air Condition
IIASA	The International Institute for Applied Systems Analysis

IPCC	Intergovernmental Panel on Climate Change
IWW	Institute for Economic Policy and Economic Research
KP	Kyoto Protocol
k-values	Coefficient of Heat Transmission
LCD	Liquid Crystal Display
LD	Landfill Directive
LED	Light Emitting Diode
MBT	Mechanical Biological Treatment
MIDAIR	Mid-America Association for Institutional Research
MSW	Municipal Solid Waste
N_2O	Nitrous Oxide
NMS	New Member States (the 10 countries which acceded to the EU in 2004)
P&M	Policies and Measures Scenario
p.a.	Per Annum / Per Year
PFC	Perfluorocarbons
PV	Photo Voltaic
RES	Renewable Energy Sources
SAVE II	Programme on Energy Efficiency
SF_6	Sulphur Hexafluoride
UBA	German Department of the Environment
UNFCCC	United Nations Framework Convention on Climate Change
VAT	Value-added Tax
Vs.	Versus
WI	Wuppertal Institute for Climate Environment Energy
WWF	World Wide Fund For Nature

UNITS

$	US Dollar
€	Euro
a	Year
Gg	Gigagram = 1 000 t
GW	Gigawatt
GWh	Gigawatt-hours
kt	kilotons = 1 000 t
ktoe	Kilo-tons / Thousand Tons of Oil Equivalent
l	Litre
Mt	Megatons
Mtoe	Million Tones of Oil Equivalent
MW	Megawatt
Pkm	Passenger Kilometre
toe	Tones of Oil Equivalent
TWh	Terawatt-hours
vkm	Vehicle Kilometre